INPC 2013

INTERNATIONAL
NUCLEAR
PHYSICS
CONFERENCE

FIRENZE, ITALY 2-7 JUNE 2013

Book of Abstracts

02 - Nuclear Structure

Foreword

In the present booklet we have collected the one-page abstracts of all contributions (invited, oral and poster) accepted at the INPC2013 Conference in the topic

Nuclear Structure

The submitted abstracts have been divided into the various topics of the Conference following mostly the indication given by the authors. In few cases, where the subject was on the borderline of two scientific areas or it appeared misplaced, the abstracts have been moved to the booklet of the more appropriate topic.

The abstracts are numbered and arranged alphabetically according to the name of the first author. In the parallel and poster sessions of the Conference, each contribution will be identified by the number of the corresponding abstract.

We wish you a pleasant and stimulating Conference.

The Organizing Committee

Nuclear Structure (NS)

NS 001.	Monte Carlo shell model towards *ab initio* nuclear structure *T. Abe, P. Mars, T. Otsuka, N. Shimizu, Y. Utsuno, J. P. Vary, and T. Yoshida* Contact email: *tabe@nt.phys.s.u-tokyo.ac.jp*
NS 002.	Spectroscopic properties of actinides and light superheavy nuclei in covariant density functional theory. *A. V. Afanasjev, O. Abdurazakov* Contact email: *afansjev@erc.msstate.edu*
NS 003.	Gamma-neutron competition above the neutron separation energy in delayed neutron emitters *J. Agramunt, A. Algora, J. Äystö, M. Bowry, V.M. Bui, R. Caballero-Folch, D. Cano-Ott, V.Eloma, T. Eronen, E. Estévez, G. F. Farrelly, M. Fallot, A. Garcia, W. Gelletly, M. B. Gomez-Hornillos, V. Gorlychev, J. Hakala, A. -A. Zakari-Issoufou, A. Jokinen, M.D. Jordan, A.Kankainen, F.G. Kondev, T. Martínez, E. Mendoza, F. Molina, I. Moore, A. Pérez, Zs.Podolyák, H. Penttilä, A.Porta, P. H. Regan, S. Rice, J. Rissanen, B. Rubio, J.L. Tain, E.Valencia, C. Weber* Contact email: *ebvalma@ific.uv.es*
NS 004.	Measurement of β-decay half-lives and delayed neutrons beyond the N = 126 shell closure *J. Agramunt, A. Algora, F. Ameil, Y. Ayyad, J. Benlliure, M. Bowry, R. Caballero-Folch, F. Calvi.no, D. Cano-Ott, G. Cortés, T. Davinson, I. Dillmann, C. Domingo-Pardo, A. Estrade, A. Evdokimov, T. Faestermann, F. Farinon, D. Galaviz, A. García-Rios, H. Geissel, W. Gelletly, R. Gernhäuser, M.B. Gómez-Hornillos, C. Guerrero, M. Heil, C. Hinke, R. Knöbel, I. Kojouharov, J. Kurcewicz, N. Kurz, Y. Litvinov, L. Maier, J. Marganiec, M. Marta, T. Mart´inez, F. Montes, I. Mukha, D.R. Napoli, Ch. Nociforo, C. Paradela, S. Pietri, Z. Podolyák, A. Prochazka, S. Rice, A. Riego, B. Rubio, H. Schaffner, Ch. Scheidenberger , K. Smith, E. Sokol, K. Steiger, B. Sun, J.L. Taín, M. Takechi, D. Testov, H. Weick, E. Wilson, J.S. Winfield, R. Wood, P. Woods* Contact email: *domingo@ific.uv.es*
NS 005.	Impact of nuclear structure on production and identification of superheavy nuclei *N.V. Antonenko* Contact email: *antonenk@theor.jinr.ru*
NS 006.	The 2012 Atomic Mass Evaluation and the Mass Tables *G. Audi, M. Wang, A.H. Wapstra, F.G. Kondev, M. MacCormick, X. Xu, B. Pfeiffer* Contact email: *amdc.audi@gmail.com*

NS 007.	Cross sections of neutron removal reactions in the isotopic chain of ^{100}Sn *L. Audirac, N. Aoi, H. Baba, P. Bednarczyk, S. Boissinot, M. Ciemala, A. Corsi, P. Doornenbal, T. Isobe, A. Jungclaus, V. Lapoux, J. Lee, K. Matsui, M. Matsushita, T. Motobayashi, A. Obertelli, S. Ota, H. Sakurai, C. Santamaria, Y. Shiga, D. Sohler, D. Steppenbeck, S. Takeuchi, R. Taniuchi, H. Wang* Contact email: *laurent.audirac@cea.fr*
NS 008.	Lifetime measurements and high spin structure of ^{36}Cl nucleus *S.Aydin, F.Recchia, M.Ionescu-Bujor, A.Gadea, S.M.Lenzi, S.Lunardi, C.A.Ur, D.Bazzacco, P.G.Bizzeti, A.M.Bizzeti-Sona, M.Bouhelal, G.de Angelis, I.Deloncle, E.Farnea, A Gottardo, F.Haas, T.Huyuk, H.Laftchiev, D.Mengoni, R.Menegazzo, C.Michelagnoli, D.R. Napoli, E.Sahin, P.P.Singh, D.Tonev, J.J.Valiente-Dobón* Contact email: *01sezgin@gmail.com*
NS 009.	Effects of the Skyrme Tensor Force on the Spin-Isospin Excitations *C.L.Bai, H.Q.Zhang, H.Sagawa, G.Colo, X.Z.Zhang, and F.R.Xu* Contact Email: *bclphy@scu.edu.cn*
NS 010.	Three-Nucleon Forces in Exotic Open-Shell Isotopes *C. Barbieri, A. Cipollone, V. Somà, T. Duguet and P. Navráti* Contact email: *c.barbieri@surrey.ac.uk*
NS 011.	The No Core Gamow Shell Model for ab-initio Nuclear Structure Calculations *B. R. Barrett, G. Papadimitriou, J. Rotureau, N. Michel, and M. Ploszajczak* Contact email: *bbarrett@physics.arizona.edu*
NS 012.	Shape coexistence and charge radii in thallium, gold and astatine isotopes studied by in-source laser spectroscopy at RILIS-ISOLDE *A. Barzakh* Contact email: *barzakh@mail.ru*
NS 013.	Beta-decay spectroscopy towards the r-process path *G. Benzoni, A.I. Morales, A. Bracco, F. Camera, F.C.L. Crespi, S. Leoni,B. Million, R. Nicolini, O. Wieland, J.J. Valiente-Dobón, A. Gottardo, A. Gadea,S. Lunardi, D. Bazzacco,E. Farnea, P. Boutachkov, M. Górska,S. Pietri,H. Weick,H. Geissel, J. Gerl, H-J. Wollersheim, A.M. Bruce,J. Grebosz,Zs. Podolyak,P.H. Regan,M. Pfützner,J. Benlliure, D. Rudolph* Contact email: *giovanna.benzoni@mi.infn.it*
NS 014.	Investigation of 0^+ states in mercury isotopes after two-neutron pickup *C. Bernards, R.F. Casten, V. Werner, P. von Brentano, D. Bucurescu, G. Graw, S. Heinze, R. Hertenberger, J. Jolie, S. Lalkovski, D.A. Meyer, D. Mücher, P. Pejovic, C. Scholl, H.-F. Wirth* Contact email: *christian.bernards@yale.edu*

NS 015.	Abstract withdrawn
NS 016.	Lifetime measurement and decay spectroscopy of ^{132}I *S. Bhattacharyya, D. Banerjee, S. K. Das, S. Bhattacharya, S. Dasgupta, T. Bhattacharjee, P. Das, R. Guin, G. Mukherjee, H. Pai* Contact email: *sarmi@vecc.gov.in*
NS 017.	Spectroscopy of neutron rich nuclei using cold neutron induced fission of actinide targets at the ILL : the EXILL campaign *A. Blanc, G. de France, M. Jentschel, U. Köster, P. Mutti, G. Simpson, T. Soldner, C. Ur, W. Urban* Contact email: *defrance@ganil.fr*
NS 018.	Two-proton radioactivity as a tool of nuclear structure *B. Blank* Contact email: *blank@cenbg.in2p3.fr*
NS 019.	Search for particle−vibration coupling in ^{65}Cu *G. Bocchi, S. Leoni, A. Bracco, S. Bottoni, G. Benzoni, G.Colò, N. Mặrginean, D. Bucurescu, Gh.Cặta-Danil, I. Cặta-Danil, D. Deleanu, D. Filipescu, I. Gheorghe, D.G. Ghiţặ, T. Glodariu, R.Licặ, C. Mihai, R.Mặrginean, A. Negret, C. R. Nitặ, T. Sava, L. Stroe, S. Toma, R. Şuvặilặ, C.A. Ur* Contact email: *giovanni.bocchi@studenti.unimi.it*
NS 020.	Structure and spectroscopy of ^{24}O drip-line nucleus from (p,p′) scattering *S. Boissinot, V. Lapoux, H. Otsu, H. Baba, R.J. Chen, A. Matta, E. Pollacco, N. Alamanos, Y. Blumenfeld, F. Flavigny, S. Franchoo, N. Fukuda, P. Gangnant, A. Gillibert, F. Hammache, C. Houarner, N. Inabe, D. Kameda, J.F. Libin, C. Louchart, M. Matsushita, T. Motobayashi, L. Nalpas, E.Y. Nikolskii, M. Nishimura, A. Obertelli, T. Onishi, E. Rindel, Ph. Rosier, H. Sakurai, F. Saillant, M. Takechi, S. Takeuchi, Y. Togano, K. Yoneda, A. Yoshida and K. Yoshida* Contact email: *simon.boissinot@cea.fr*
NS 021.	Quadrupole collectivity in neutron-rich Cd isotopes investigated via Coulomb excitation *S. Bönig, C. Bauer, A. Hartig, S. Ilieva, T. Kröll, M. Scheck* Contact email: *sboenig@ikp.tu-darmstadt.de*

NS 022.	A shell model description of E3 transition strengths in sd shell nuclei *M. Bouhelal, F. Haas, E. Caurier, F. Nowacki* Contact email: *m_bouhelal@yahoo.fr*
NS 023.	Extended interacting boson model description up to ^{98}Pd nuclei in the A~100 transitional region *M. Böyükata, E. Ellinger, C. Fransen, J. Jolie* Contact email: *mboyukata@yahoo.com*
NS 024.	Quantum shape phase transitions from sphericity to deformation for Bose-Fermi systems and the effect of the odd particle around the critical point *M. Böyükata, C. E. Alonso, J. M. Arias, L. Fortunato, A. Vitturi* Contact email: *mboyukata@yahoo.com*
NS 025.	A microscopic model beyond mean-field: from giant resonances properties to the fit of new effective interactions *M. Brenna, G. Colò, X. Roca-Maza, P. F. Bortignon, K. Moghrabi, M. Grasso* Contact email: *marco.brenna@mi.infn.it*
NS 026.	Beta decay studies of the N=Z and waiting point nucleus ^{72}Kr *J.A. Briz, M.J.G. Borge, A. Maira1, E. Nácher, A. Perea, O. Tengblad, J. Agramunt, A. Algora, E. Estévez, B. Rubio, J.L. Taín, S. Courtin, Ph. Dessagne, F. Maréchal, Ch. Miehé, E. Poirier, L.M. Fraile, A. Deo, G. Farrelly, W. Gelletly, Z. Podolyak* Contact email: *jose.briz@csic.es*
NS 027.	Semi-microscopic description of the proton- and neutron-induced backbending phenomena in some deformed even-even rare earth nuclei *R. Budaca, A. A. Raduta* Contact email: *rbudaca@theory.nipne.ro*
NS 028.	Nuclear Structure studies with the CRIS beamline at ISOLDE, CERN *I. Budinčević, J. Billowes, M.L. Bissel, T. E. Cocolios, R. De Groote, S. De Schepper, K. T. Flanagan, R. F. Garcia Ruiz, H. Heylen, K. M. Lynch, B. Marsh, P.J. Mason, G. Neyens, J. Papuga, T. J. Procter, M.M. Rajabali, R.E. Rossel, S. Rothe, I. Strashnov, H. H. Stroke, D. Verney, P.M. Walker, K. Wendt, R.T. Wood* Contact email: *ivan.budincevic@fys.kuleuven.be*
NS 029.	Emergent collectivity from experimental δV_{pn} values and calculated orbit overlaps *R.Burcu Cakirli, D. Bonatsos, S. Karampagia, R.F. Casten, K. Blaum* Contact email: *rburcu@istanbul.edu.tr*

NS 030.	An approximate solution of the Dirac equation with trigonometric Pöschl Teller potential for any κ state *N. Candemir* Contact email: *ncandemi@anadolu.edu.tr*
NS 031.	Properties of Single-particle States in a Fully Self-consistent Particle Vibration Coupling Approach *Li-Gang Cao, G. Colò, H. Sagawa, P. F. Bortignon* Contact email: *caolg@impcas.ac.cn*
NS 032.	α-decay and excited states of ^{111}Xe *L. Capponi, J. F. Smith, C. Scholey, P. Ruotsalainen, P. Rahkila, B. Hadinia, L. Bianco, A. J. Boston, H. C. Boston, D. M. Cullen, X. Derkx, M. Drummond, T. Grahn, P. T. Greenlees, L. Grocutt, U. Jakobsson, D. T. Joss, R. Julin, S. Juutinen, M. Labiche, M. Leino, K. Leach, C. McPeake, K. F. Mulholland, P. Nieminen, D. O'Donnell, E. S. Paul, P. Peura, M. Sandzelius, J. Saren, B. Saygi, J. Sorri, A. Thornthwaite, M. J. Taylor, J. Uusitalo* Contact email: *luigi.capponi@uws.ac.uk*
NS 033.	Isospin mixing at finite temperature in ^{80}Zr *S. Ceruti, A.Giaz, F.Camera, R.Avigo, G.Benzoni, N.Blasi, A.Bracco, S.Brambilla, A.Corsi, F.Crespi, S.Leoni, A.I.Morales-Lopez, B.Million, L.Pellegri, R.Nicolini, S.Riboldi, V.Vandone, O.Wieland, M.Bellato, D.Bortolato, C.Fanin, A.Gottardo, F.Gramegna, V.Kravchuck, T.Marchi, V.Modamio, D.R.Napoli, E.Shain, J.J.Valiente-Dobon, D.Bazzacco, E.Farnea, D.Mengoni, C.Michelagnoli, D.Montanari, F.Recchia, C.Ur, M.Ciemala, M.Kmiecik, A.Maj, S.Myalski, J.Styczen, M.Zieblinski, M.Bruno, M.D'Agostino, G.Casini, R.De Palo* Contact email: *simone.ceruti@unimi.it*
NS 034.	Study of Ground-state configuration of neutron-rich Aluminium isotopes through Coulomb Breakup *S. Chakraborty, U. Datta Pramanik, T. Aumann, S. Beceiro, T. Le Bleis, K. Boretzky, D. Cotrina-Gil, C. Caesar, M. Chariter, W. N. Catford, D. Gonzalez-Diaz, H. Emling, P. Diaz-Fernandez, L. M. Fraile, G. De Angelis, O. Ershova, H. Geissel, M. Heil, M. Heine, B. Jonson, A. Kelic, H. T. Johansson, R. Krucken, T. Kroll,C. Langer, Y. Leiffel, G. Munzenberg, J. Marganiec, C. Nociforo, M. A. Najafi, V. Panin, R.Plag, H. A.Pol, S. Paschalis, A. Rahaman, R. Reifarth, D. Rossi, H. Simon, C. Scheidenberger, S. Typel, J. Taylor, Y. Togano, V. Volkov, H. Weick, A.Wagner, F. Wamers, M. Weigand, J. Winfield, M. Zoric* Contact email: *ushasi.dattapramanik@saha.ac.in*

NS 035.	Search for multi-quasiparticle isomers in ^{254}Rf *J. Chen, F.G. Kondev, D. Seweryniak, I. Ahmad, M. Albers, M. Alcorta, P. Bertone, M.P.Carpenter, C.J. Chiara, H.M. David, D.T. Doherty, J.P. Greene, P. Greenlees, D.J. Hartley, K.Hauschild, C.R. Hoffman, S.S. Hota, R.V.F. Janssens, T.L. Khoo, J. Konki, T. Lauritsen, C.Nair, Y. Qiu, A.M. Rogers, G. Savard, S. Stolze, S. Zhu* Contact email: *kondev@anl.gov*
NS 036.	Correlation Studies of the Low-Energy ^{6}Be Spectrum *V. Chudoba, A.S. Fomichev, I.E. Egorova, S.N. Ershov, M.S. Golovkov, A.V. Gorshkov, V.A. Gorshkov, L.V. Grigorenko, G. Kami´nski, S.A. Krupko, I.G. Mukha, Yu.L. Parfenova, S.I. Sidorchuk, R.S. Slepnev, L. Standyło, S.V. Stepantsov, G.M. Ter-Akopian, R. Wolski, M.V. Zhukov* Contact email: *chudoba@jinr.ru*
NS 037.	Giant Dipole Resonance decay of hot rotating ^{88}Mo *M. Ciemała, M. Kmiecik, A. Maj, V.L. Kravchuk, F. Gramegna, S. Barlini, G. Casini, F. Camera* Contact email: *Michal.Ciemala@ifj.edu.pl*
NS 038.	Shape coexistence in neutron-rich Sr and Kr isotopes: Prompt spectroscopy after Coulomb excitation at REX-ISOLDE, CERN and after neutron induced fission of ^{235}U at ILL *E.Clément* Contact email: *clement@ganil.fr*
NS 039.	Quantum Nucleodynamics: Bottom-up nuclear structure theory *Norman D. Cook* Contact email: *cook@res.kutc.kansai-u.ac.jp*
NS 040.	Mass dependence of short-range correlations in nuclei and the EMC effect *W. Cosyn, M. Vanhalst, C. Colle, J. Ryckebusch* Contact email: *wim.cosyn@ugent.be*
NS 041.	Study of the γ decay of high-lying states in ^{208}Pb via inelastic scattering of ^{17}O ions *F.C.L. Crespi, A. Bracco, S. Leoni, L. Pellegri, D. Assanelli, G. Benzoni, N. Blasi, C. Boiano, S. Bottoni, S. Brambilla, F. Camera, S. Ceruti, A. Giaz, B. Million, A.I. Morales, R. Nicolini, D. Paradiso, S. Riboldi, V. Vandone, O. Wieland, P. Bednarczyk, M. Ciemala, J. Grebosz, M. Kmiecik, M. Krzysiek, A. Maj, K. Mazurek, M. Zieblinski, D. Bazzacco, M. Bellato, B. Birkenbach, D. Bortolato, E. Calore, G. De Angelis, E. Farnea, A. Gadea, A. Görgen, A. Gottardo, R. Isocrate, S. Lenzi, S. Lunardi, D. Mengoni, C. Michelagnoli, P. Molini, D.R. Napoli, F. Recchia, E. Sahin, B. Siebeck, S. Siem, C. Ur, J.J. Valiente Dobon* Contact email: *fabio.crespi@mi.infn.it*

NS 042.	Shell structure, cluster structure and shell-like cluster-structure *József Cseh* Contact email: *cseh@atomki.mta.hu*
NS 043.	Giant dipole resonance in highly excited nuclei *Nguyen Dinh Dang* Contact email: *dang@riken.jp*
NS 044.	Shape isomers and their clusterization *Judit Darai* Contact email: *darai@atomki.mta.hu*
NS 045.	Preliminary results of a more accurate measurement of the radiative 4^+ to 2^+ transition in ^{8}Be *V.M.Datar, D.R. Chakrabarty, Suresh Kumar, V. Nanal, S.P. Behera, E.T. Mirgule, A. Mitra, K. Ramachandran, P.C. Rout, A. Shrivastava, R.G. Pillay, P. Sugathan, C.J. Lister, D. Jenkins and O. Roberts* Contact email: *vivek.datar@gmail.com*
NS 046.	Instabilities in Skyrme functionals: identification, detection and applications *D. Davesne, A. Pastore* Contact email: *davesne@ipnl.in2p3.fr*
NS 047.	Ab initio calculations with nonsymmetrized hyperspherical harmonics for realistic NN potential models *S. Deflorian, N. Barnea, W. Leidemann, G. Orlandini* Contact email: *deflorian@science.unitn.it*
NS 048.	Effect of quasi particle number fluctuations on thermodynamical properties of ^{183}W *V. Dehghani , Z. Kargar* Contact email: *vahiddehghani18@gmail.com*
NS 049.	Effect of statistical fluctuations on thermodynamical properties of ^{98}Mo *V. Dehghani , Z. Kargar* Contact email: *vahiddehghani18@gmail.com*
NS 050.	Spectroscopy of ^{9}Be and observation of neutron halo structure in the states of positive parity rotational band *A.S. Demyanova, A.A.Ogloblin, A.N.Danilov, S.V.Dmitriev, S.A.Goncharov, N.Burtebaev, J.Burtebaeva, N.Saduev, T.L.Belyaeva, H.Suzuki, R.Nishikiori, A.Ozawa, D.Nagae, T.Moriguchi, Y.Ishibashi, H.Ooishi, K.Yokoyama, Y.Abe, K.Okumura, S.Fukuoka, S.Ito, T.Niwa, T.Komatsubara, S.Kubono* Contact email: *a.s.demyanova@bk.ru*

NS 051.	Spectroscopy of exotic states of ^{13}C *A.S.Demyanova, A.A. Ogloblin, A.N. Danilov, S.V. Dmitriev, T.L. Belyaeva, N. Burtebaev, S.A. Goncharov, Yu.B. Gurov, V.A. Maslov, Yu. E. Penionzhkevich, Yu.G. Sobolev, W. Trzaska, G.P. Tyurin, P. Heikkinen, S.V. Khlebnikov, R. Julin* Contact email: *a.s.demyanova@bk.ru*
NS 052.	Probing the Character of the Pygmy Dipole Resonance *V.Derya, J. Endres, M. N. Harakeh, N. Pietralla, D. Savran, M. Spieker, H. J. Wörtche, A. Zilges* Contact email: *derya@ikp.uni-koeln.de*
NS 053.	What do the conditions of exact pseudospin symmetry in nuclear relativistic models mean in real nuclei? *B. Desplanques, S. Marcos* Contact email: *marcoss@unican.es*
NS 054.	Structure study of ^{110}Cd via a high-statistics β^+/EC-decay ^{110}In measurement *A. Diaz Varela, P.E. Garrett, G.C. Ball, J.C. Bangay, D.S. Cross, G.A. Demand, P. Finlay, A.B. Garnsworthy, K.L. Green, G. Hackman, B. Jigmeddorj, W.D. Kulp, K.G. Leach, J.N.Orce, A.A. Phillips, A.J. Radich, E.T. Rand, M.A. Schumaker, C. Sumithrarachchi, C.E. Svensson, S. Triambak, J. Wong, J.L. Wood, S.W. Yates* Contact email: *adiazvar@uoguelph.ca*
NS 055.	Precision mass measurements of short-lived nuclei for nuclear structure studies *J. Dilling* Contact email: *JDilling@TRIUMF.CA*
NS 056.	Effective theory for low-energy nuclear energy density functionals *J. Dobaczewski, K. Bennaceur, and F. Raimondi* Contact email: *Jacek.Dobaczewski@fuw.edu.pl*
NS 057.	Spectroscopy and Lifetime Measurement in Neutron-deficient Re and Ir nuclei *M. Doncel, B. Cederwall, T. Bäck, F. G. Moradi, T. Grahn, P. T. Greenlees, K. Hauschild, A. Herzan, U. Jakobsson, R. Julin, S. Juutinen, S. Ketelhut, M. Leino, P. Nieminen, P. Peura, P. Rahkila, P. Ruotsalainen, M. Sandzelius, J. Sarén, C. Scholey, J. Sorri, J. Uusitalo, G. Alharsham, D. M. Cullen, M. Procter, M. Taylor* Contact email: *doncel@kth.se*
NS 058.	Number-projected electric quadrupole moment of even-even proton-rich nuclei in the isovector pairing case *M. Douici, N.H. Allal, M. Fellah, N. Benhamouda and M.R. Oudih* Contact email: *nallal@usthb.dz*

NS 059.	Deep inelastic reactions and isomers in neutron-rich nuclei across the perimeter of the A = 180-190 deformed region *G.D.Dracoulis, G.J. Lane, A.P. Byrne, H. Watanabe, R.O. Hughes, F.G. Kondev, M.Carpenter, R.V.F. Janssens, T.Lauritsen, C.J. Lister, D. Seweryniak, S. Zhu, P. Chowdhury, Y. Shi, F.R. Xu* Contact email: *george.dracoulis@anu.edu.au*
NS 060.	Superheavy Elements studied with TASCA at GSI *Ch.E. Düllmann* Contact email: *duellmann@uni-mainz.de*
NS 061.	Energy Density Functional description of nuclear quantum liquid and clusters states *J.-P. Ebran, E. Khan, T. Niksic, D. Vretenar* Contact email: *jean-paul.ebran@cea.fr*
NS 062.	Theoretical studies of isovector soft dipole mode *I.A. Egorova, S. N. Ershov, A. S. Fomichev, L. V. Grigorenko, M. S. Golovkov, Yu. L. Parfenova* Contact email: *i.a.egorova@gmail.com*
NS 063.	Magnetic moment measurement of ^{125}Sb with a new spin-oriented nuclei facility: POLAREX *A. Etile, A. Astier, S. Cabaret, C. Gaulard, G. Georgiev, F. Ibrahim, J.Nikolov, S. Roccia, G. Simpson, J.R. Stone, N.J. Stone, D. Verney, M. Veskovic* Contact email: *etile@csnsm.in2p3.fr*
NS 064.	Stellar electron-capture rates on nuclei based on Skyrme functional *A.F. Fantina, E. Khan, G. Colò, N. Paar, D. Vretenar* Contact email: *afantina@ulb.ac.be*
NS 065.	In-Gas Laser Ionization and Spectroscopy experiments *R. Ferrer, L. Ghys, M. Huyse, Yu. Kudryavtsev, D. Radulov, C. Van Beveren, P. Van den Bergh, P. Van Duppen* Contact email: *Rafael.Ferrer@fys.kuleuven.be*
NS 066.	Spectroscopy of Element 115 Decay Chains *U. Forsberg, D. Rudolph, P. Golubev, L.G. Sarmiento, A. Yakushev, L.-L. Andersson, Ch.E. Düllmann, J.M. Gates, K.E. Gregorich, F.P. Hessberger, R.-D. Herzberg, J. Khuyagbaatar, J.V. Kratz, K. Rykaczewski, M. Schädel, S. Åberg, D. Ackermann, M. Block, H. Brand, B.G. Carlsson, D. Cox, X. Derkx, A. Di Nitto, K. Eberhardt, J. Even, C. Fahlander, J. Gerl, C.J. Gross, E. Jäger, B. Kindler, J. Krier, I. Kojouharov, N. Kurz, B. Lommel, A. Mistry, C. Mokry, H. Nitsche, J.P. Omtvedt, P. Papadakis, I. Ragnarsson, J. Runke, H. Schaffner, B. Schausten, P. Thörle-Pospiech, T. Torres, A. Türler, A. Ward, N. Wiehl* Contact email: *Ulrika.Forsberg@nuclear.lu.se*

NS 067.	Review of critical point symmetries and shape phase transitions *L. Fortunato* Contact email: *fortunat@pd.infn.it*
NS 068.	Neutron halo in ^{14}B studied via reaction cross sections *M. Fukuda, D. Nishimura, S. Suzuki, M. Takechi, K. Iwamoto, M. Mihara, K. Matsuta, S. Wakabayashi, M. Yaguchi, J. Oono, Y. Morita, Y. Kamisho, M. Nagashima, T. Ohtsubo, T. Izumikawa, T. Ogura, K. Abe, N. Kikukawa, T. Sakai, D. Sera, T. Suzuki, T. Yamaguchi, K. Sato, H. Furuki, S. Miyazawa, N. Ichihashi, J. Kohno, S. Yamaki, A. Kitagawa, S. Sato, and S. Fukuda* Contact email: *mfukuda@phys.sci.osaka-u.ac.jp*
NS 069.	Present status of study on alpha-particle condensation in nuclei *Y. Funaki, H. Horiuchi, G. Röpke, P. Schuck, A. Tohsaki, T. Yamada* Contact email: *funaki@riken.jp*
NS 070.	Recent progress in the description of pairing in nuclei (at zero and finite temperature) *D. Gambacurta, D. Lacroix* Contact email: *gambacurta@ganil.fr*
NS 071.	Microscopic Optical Potential with Two and Three Body Forces for nucleon-Nucleus Scattering *Y. K. Gambhir* Contact email: *yogy@phy.iitb.ac.in*
NS 072.	Propagation of uncertainties in the Skyrme energy-density-functional model *Y. Gao, J. Dobaczewski, M. Kortelainen, B. G. Carlsson, J. Toivanen and D. Tarpanov* Contact email: *whokillv@gmail.com*
NS 073.	The evolving structure of the Cd isotopes *P.E. Garrett* Contact email: *pgarrett@physics.uoguelph.ca*
NS 074.	Isomer and beta decay spectroscopy in the ^{132}Sn region with EURICA *Guillaume Gey, Andrea Jungclaus, Gary Simpson, Jan Taprogge* Contact email: *andrea.jungclaus@csic.es*
NS 075.	Spherical and deformed structure in N = 50 medium mass nuclei *S. K. Ghorui, C. R. Praharaj* Contact email: *surja@iitrpr.ac.in*

NS 076.	Beta-delayed fission of neutron-deficient Fr and At isotopes *L. Ghys* Contact email: *lars.ghys@fys.kuleuven.be*
NS 077.	Statistical gamma-ray emission of gold and its astrophysical implications *F. Giacoppo, F. Bello, L. Bernstein, D. Bleuel, R.B. Firestone, A. Görgen, M. Guttormsen, T. W. Hagen, M. Klintefjord, P. E. Koehler, A.C. Larsen, H. T. Nyhus, T. Renstrøm, E. Sahin and S. Siem* Contact email: *francesca.giacoppo@fys.uio.no*
NS 078.	Observation of isomers in N=100 neutron rich nuclei *S. Go, D. Kameda, T. Kubo, N. Inave, N. Fukuda, H. Takeda, H. Suzuki, K. Yoshida, K. Kusaka, K. Tanaka, Y. Yanagisawa, M. Ohtake, H. Sato, Y. Shimizu, H. Baba, M. Kurokawa, D. Nishimura, T. Ohnishi, N. Iwasa, A. Chiba, T. Yamada, E. Ideguchi, R. Yokoyama, T. Fujii, H. Nishibata, K. Ieki, D. Murai, S. Momota, Y. Sato, J. Hwang, S. Kim, O. B. Tarasov, D. J. Morrissey, G. Simpson* Contact email: *go@cns.s.u-tokyo.ac.jp*
NS 079.	Why is Lead so Kinky? *P.M. Goddard, P.D. Stevenson, A. Rios* Contact email: *p.goddard@surrey.ac.uk*
NS 080.	Very neutron rich light nuclei and α-cluster states in neutron rich light nuclei *V. Z. Goldberg* Contact email: *goldberg@comp.tamu.edu*
NS 081.	Recent results in quantum chaos and its applications to nuclei and particles *J.M.G. Gomez, L. Munoz, A. Relano, J. Retamosa, R A. Molina, E. Faleiro* Contact email: *gomezk@nuclear.fis.ucm.es*
NS 082.	The Newly-Explored Region Beyond N=126 Reveals Unexpected Features of the Nuclear Structure *A. Gottardo* Contact email: *andrea.gottardo@lnl.infn.it*
NS 083.	Semiclassical Description of a Single Particle Spectrum of a Nucleon in the Harmonic Oscillator Mean Field with Spin-Orbit Coupling *R. Gupta, S.S. Malik* Contact email: *rajiv_gupta_mirage@yahoo.com*
NS 084.	Scissors Strength in the Quasi-Continuum of Actinides *M. Guttormsen, L.A. Bernstein, A. Bürger, F. Gunsing, A. Görgen, A.C. Larsen, T. Renstrøm, S. Siem, M. Wiedeking, T. Wiborg Hagen, and J.N. Wilson* Contact email: *magne.guttormsenl@fys.uio.no*

NS 085.	High-lying Gamow-Teller excited states in the deformed nuclei, ^{76}Ge and ^{82}Se, by the smearing of the Fermi surface in Deformed Quasi-particle RPA (DQRPA) *Eunja Ha, K.S.Kim, Myung-Ki Cheoun* Contact email: *eunhasky@hotmail.com*
NS 086.	Structure of ^{42}Ca Coulomb excited states *K.Hadyńska-Klęk, P.Napiorkowski, A.Maj, F.Azaiez, J.J.Valiente-Dobón, M. Kicińska-Habior, F. Nowacki* *Contact email: kasiah@slcj.uw.edu.pl*
NS 087.	Advances in coupled-cluster computations of medium mass and neutron rich nuclei *G. Hagen* Contact email: *hageng@ornl.gov*
NS 088.	Structure of the nuclei with Z~ 100 investigated by a particle-number conserving method based on a cranked shell model *Xiao-tao He, Zhen-hua Zhang, Werner Scheid* Contact email: *he.xiaotao05@googlemail.com*
NS 089.	Nuclear Structure Studies by Means of (p,p′ γ) Experiments *A. Hennig, T. Ahn, V. Anagnostatou, N. Cooper, M. Elvers, J. Endres, P. Goddard, A. Heinz, R. Hughes, G. Ilie, D. Radeck, T. J. Ross, D. Savran, V. Werner, and A. Zilges* Contact email: *hennig@ikp.uni-koeln.de*
NS 090.	Exploring the stability of super heavy elements *G. Henning, T.L. Khoo, A. Lopez-Martens, D. Seweryniak, M. Alcorta, M. Asai, B. B. Back, P. Bertone, D. Boiley, M. P. Carpenter, C. J. Chiara, P. Chowdhury, B. Gall, P. T. Greenlees, G. Gurdal, K. Hauschild, A. Heinz, C. R. Hoffman, R. V. F. Janssens, A. V. Karpov, B. P.Kay, F. G. Kondev, S. Lakshmi, T. Lauristen, C. J. Lister, E. A. McCutchan, C. Nair, J. Piot, D. Potterveld, P. Reiter, N. Rowley, A. M. Rogers, and S. Zhu* Contact email: *araceli.lopez-martens@csnsm.in2p3.fr*
NS 091.	Spectroscopy of light bismuth isotopes *A. Herzáň, K. Auranen, T. Grahn, P. Greenlees, K. Hauschild, U. Jakobsson, R. Julin, S.Juutinen, J. Konki, M. Leino, A. Lopez-Martens, T. Lönnroth, M. Nyman, J. Pakarinen, J.Partanen, P. Peura, P. Rahkila, P. Ruotsalainen, M. Sandzelius, J. Sarén, C. Scholey, J. Slotte, J. Sorri, S. Stolze, J. Uusita* Contact email: *anherzan@jyu.fi*
NS 092.	Nuclear Structure of the Heaviest Elements Investigated at SHIP - GSI *F.P. Heßberger* Contact email: *f.p.hessberger@gsi.de*

NS 093.	Complete Spectroscopy of Negative Parity States in ^{208}Pb with $E_x \leq 6.5$MeV *A.Heusler, Th. Faestermann, R. Hertenberger, H.-F. Wirth, P. von Brentano* Contact email: *A.Heusler@mpi-hd.mpg.de*
NS 094.	Shell model description of high spin isomers in Po and Rn isotopes *Koji Higashiyama, Naotaka Yoshinaga* Contact email: *koji.higashiyama@it-chiba.ac.jp*
NS 095.	Application of the generator coordinate method to neutron-rich Se and Ge isotopes *Koji Higashiyama, Naotaka Yoshinaga* Contact email: *koji.higashiyama@it-chiba.ac.jp*
NS 096.	Tensor correlations probed by electroweak responses *W. Horiuchi, Y. Suzuki* Contact email: *whoriuchi@nucl.sci.hokudai.ac.jp*
NS 097.	Unified description of shell and cluster coexistence in ^{16}O with a five-body model *W. Horiuchi, Y. Suzuki* Contact email: *whoriuchi@nucl.sci.hokudai.ac.jp*
NS 098.	Coulomb excitation of the band-terminating 12^+ yrast trap in ^{52}Fe *T. Hüyük, A. Gadea, C. Domingo, C. A. Ur, D. Bazzacco, E. Farnea, D. Mengoni, J. J.Valiente-Dob´on, G. de Angelis, A. Gottardo, D. R. Napoli, V. Modamio, A. Bracco, G. Benzoni, S. Brambilla, F. Camera, F. Crespi, S. Leoni, B. Million, D.Montanari, N. Blasi, O. Wieland, D.Di Julio, C. Fahlander, J. Gellanki, P. Golubev, R. Hoischen, D. Rudolph, A.Jungclaus, M.A.Bentley, A. Obertelli, W. Korten, B. Quintana, M. Doncel, M. Górska, P. Boutachkov, J.Gerl, S. Pietri, H. J. Wollersheim, H. Grawe, E. Merchan, I. Kojouharov, N. Kurz, H.Schaffner, N. Goel, R. Hoischen, T. Engel, T. Habermann, M. Reese, P. Singh* Contact email: *huyuk@ific.uv.es*
NS 099.	Magnetic moment measurement in ^{72}Zn using the Transient Field technique and Coulomb excitation in inverse kinematics *A. Illana Sison, A. Jungclaus, R. Orlandi, J.A. Briz, A. Perea, R. Gernhäuser, D. Mücher, J. Leske, C. Bauer, C. Stahl, M. Rajabali, J. Cederkall, J. Pakarinen and P.M. Walker* Contact email: *andres.illana@csic.es*
NS 100.	Decay pattern of the Pygmy Dipole Resonance in ^{130}Te *J. Isaak, J. Beller, E. Fiori, M. Krtička, B. Löher, N. Pietralla, C. Romig, G. Rusev, D.Savran, M. Scheck, J. Silva, K. Sonnabend, A. Tonchev, W. Tornow, H. Weller and M. Zweidinger* Contact email: *j.isaak@gsi.de*

NS 101.	Unified studies of neutron-excess systems from bound to continuum *Makoto Ito* Contact email: *itomk@kansai-u.ac.jp*
NS 102.	Candidate for the linear-like 3α cluster state in $^{12}\mathrm{C}$ *M. Itoh, H. Akimune, M. Fujiwara, U. Garg, T. Kawabata, K. Kawase, T. Murakami, K. Nakanishi, Y. Nakatsugawa, H. Sakaguchi, S. Terashima, M. Uchida, Y. Yasuda, M. Yosoi, J. Zenihiro* Contact email: *itoh@cyric.tohoku.ac.jp*
NS 103.	Spectroscopic factors from the $^{111}\mathrm{Cd}(\vec{d}, p)^{112}\mathrm{Cd}$ single neutron transfer reaction *D.S. Jamieson, P.E. Garrett, G.C. Ball, G.A. Demand, T. Faestermann, P. Finlay, K.L. Green, R.Hertenberger, R. Krücken, K.G. Leach, A.A.Phillips, C.S. Sumithrarachchi, C.E. Svensson, S.Triambak, H.-F. Wirth, J. Wong* Contact email: *jamiesoa@uoguelph.ca*
NS 104.	Study of shape transition in the neutron-rich Os isotopes *P.R. John, V. Modamio, J.J. Valiente-Dobón, D. Mengoni, S. Lunardi, T. Alexander, G. de Angelis, N. Ashwood, M. Barr, D. Bazzacco, P.G. Bizzeti, A.M. Bizzeti-Sona, S. Bottoni, M. Bowry, A. Bracco, F. Browne, M. Bunce, A. Gadea, F. Camera, L. Corradi, F.C.L. Crespi, E. Farnea, E. Fioretto, A. Gottardo, Tz. Kokalova, W. Korten, A. Kuşoğlu, S. Lenzi, S. Leoni, C. Michelagnoli, T. Mijatović, G. Montagnoli, D. Montanari, D.R. Napoli, Zs. Podolyák, G. Pollarolo, F. Recchia, O.J. Roberts, E. Sahin, M.-D. Salsac, F. Scarlassara, M. Sferrazza, A.M. Stefanini, S. Szilner, C.A. Ur, J. Walshe, C. Wheldon* Contact email: *philipp.john@pd.infn.it*
NS 105.	A Study of Empirical Mass Formulae *E.F. Jones, P.M. Gore* Contact email: *e.f.jones.phys@gmail.com*
NS 106.	Discovery of microsecond isomers in neutron-rich rare-earth region by in-flight fission of 345 MeV/nucleon $^{238}\mathrm{U}$ *D. Kameda, T. Kubo, N. Fukuda, H. Takeda, H. Suzuki, K. Yoshida, K. Kusaka, K. Tanaka, Y. Yanagisawa, M. Ohtake, N. Inabe, H. Sato, Y. Shimizu, H. Baba, M. Kurokawa, D. Nishimura, T. Ohnishi, N. Iwasa, A. Chiba, T. Yamada,E. Ideguchi, S. Go, R. Yokoyama, T. Fujii, H. Nishibata, K. Ieki, D. Murai, S. Momota, Y. Sato, J. Hwang, S. Kim, O. B. Tarasov, D. J. Morrissey, B. M. Sherrill, and G. Simpson* Contact email: *kameda@ribf.riken.jp*

NS 107.	Study of the structure of light nuclei far from the stability *G. Kamiński, A.S. Fomichev, A.C. Barayeva, A.A. Bezbakh, V. Chudoba, H. Czyrkowski, R.Dąbrowski, W. Dominik, S. Enkhbold, M.S. Golovkov, V.A. Gorshkov, A.V. Gorshkov, L.V.Grigorenko, B. Hnatio, Z. Janas, P. Jaluvkova, A. Knyazev S.A. Krupko, A. Korgul, M.Kuich, C. Mazzocchi, M. Mentel, S. Mianowski, K. Miernik, P. Plucinski, M. Pfutzner, P.G.Sharov, S.I. Sidorchuk, R.S. Slepnev, S.V. Stepantsov, G.M. Ter-Akopian, R Wolski* Contact email: *Grzegorz.Kaminski@ifj.edu.pl*
NS 108.	g-factor measurement of 7^- isomeric state in ^{128}Ba *Jasmeet Kaur, N. Bansal, Vijay R. Sharma, H. Sisodia, R. Kumar, V. Kumar, A.K. Bhati, R.K. Bhowmik* Contact email: *meetu_a@yahoo.co.in*
NS 109.	Search for alpha condensed states in ^{24}Mg *T. Kawabata, T. Adachi, M. Fujiwara, K. Hatanaka, Y. Ishiguro, M. Itoh, Y. Maeda, H. Matsubara, H. Miyasako, Y. Nozawa, T. Saito, S. Sakaguchi, Y. Sasamoto, Y. Shimizu, T. Takahashi, A. Tamii, S. Terashima, H. Tokieda, N. Tomida, T. Uesaka, M. Uchida, Y. Yasuda, N. Yokota, H. P. Yoshida, and J. Zenihiro* Contact email: *kawabata@scphys.kyoto-u.ac.jp*
NS 110.	Coulomb excitation of ^{196,198,200,202}Po studied at REX-ISOLDE with the Miniball γ spectrometer *N.Kesteloot, B. Bastin, N. Bree, P. Butler, E. Clement, J. Diriken, L. Gaffney, T. Grahn, M. Huyse, J. Konki, T. Kroell, B. Marsh, E. Piselli, E. Rapisarda, M. Scheck, M. Sjoedin, J. Van de Walle, P. Van Duppen, D. Voulot, N. Warr, F. Wenander, K. Wrzosek-Lispka and M. Zielinska* Contact email: *nele.kesteloot@fys.kuleuven.be*
NS 111.	Neutron skin thickness in the Skyrme EDF models *M. Kortelainen, J. Erler, N. Birge, Y. Gao, W. Nazarewicz, E. Olsen* Contact email: *markus.kortelainen@jyu.fi*
NS 112.	Mass measurements at ISOLDE *M. Kowalska* Contact email: *kowalska@cern.ch*
NS 113.	Establishing the neutron magic number N = 32 with mass measurements of $^{53;54}$Ca using ISOLTRAP's MR-TOF MS *S. Kreim, D. Atanasov, D. Beck, K. Blaum, Ch. Böhm, Ch. Borgmann, M. Breitenfeldt, R. B.Cakirli, T. E. Cocolios, S. Eliseev, S. George, F. Herfurth, A. Herlert, M. Kowalska, Yu. A.Litvinov, D. Lunney, V. Manea, E. Minaya Ramirez, S. Naimi, D. Neidherr, M. Rosenbusch, L. Schweikhard, J. Stanja, F. Wienholtz, R. N. Wolf, K. Zuber* Contact email: *skreim@cern.ch*

NS 114.	Coulomb excitation of exotic nuclei at REX-ISOLDE with MINIBALL *T. Kröll* Contact email: *tkroell@ikp.tu-darmstadt.de*
NS 115.	Investigation of low-energy dipole modes in the heavy deformed nucleus ^{154}Sm via inelastic polarized proton scattering at zero degree *A. Krugmann, D. Martin, P. von Neumann-Cosel, N. Pietralla, I. Poltoratska, V. Yu. Ponomarev, A. Tamii, C. Iwamoto, K. Yoshida* Contact email: *krugmann@ikp.tu-darmstadt.de*
NS 116.	Overview of the Search for New Isotopes and New Isomers at RIKEN RI Beam Factory *T. Kubo, D. Kameda, H. Suzuki, N. Fukuda, H. Takeda, N. Inabe, R. Yokoyama, S. Go, and E. Ideguchi* Contact email: *kubo@ribf.riken.jp*
NS 117.	β decay ^{231}Th→^{231}Pa *A.A. Kurteva* Contact email: *ann.kurteva17@gmail.com*
NS 118.	About the renormalization of weak interaction constants in nuclei *A.A. Kurteva, V.E. Mitroshin* Contact email: *ann.kurteva17@gmail.com*
NS 119.	Nuclear Vorticity in Giant Resonances: Skyrme RPA Analysis *J. Kvasil, V.O. Nesterenko, W. Kleinig, and P.-G. Reinhard* Contact email: *kvasil@ipnp.troja.mff.cuni.cz*
NS 120.	Precision measurement of the Electromagnetic dipole strengths in ^{11}Be *E. Kwan* Contact email*: kwan12@llnl.gov*
NS 121.	Isospin Symmetry Violation in sd Shell Nuclei *Y. H. Lam, N. A. Smirnova, E. Caurier* Contact email: *lamyihua@theorie.ikp.physik.tu-darmstadt.de*
NS 122.	Spectroscopy of the drip-line ^{6,7,8}He nuclei via direct reactions on proton *V. Lapoux, X. Mougeot, W. Mittig, N. Keeley, N. Alamanos, F. Auger, B. Avez, D. Beaumel, Y. Blumenfeld, R. Dayras, A. Drouart, C. Force, L. Gaudefroy, A. Gillibert, J. Guillot, H. Iwasaki, T. Kalanee, L. Nalpas, E. Pollacco, T. Roger, P. Roussel-Chomaz, D. Suzuki, K. Kemper, T. Mermizedakis, A. Pakou, J-A. Scarpaci, K. Rusek, C. Simenel, I.Strojek, R. Wolski* Contact email: *vlapoux@cea.fr*

NS 123.	Description of light nuclei (10 ≤Z,N ≤18) with the multiparticle-multihole Gogny energy density functional *J. Le Bloas, N. Pillet, J.-M. Daugas, M. Dupuis* Contact email: *julien.lebloas@cea.fr*
NS 124.	Do light nuclei exhibit "collective" motions? *W. Leidemann, G. Orlandini, N. Barnea, S. Bacca* Contact email: *winfried.leidemann@unitn.it*
NS 125.	Nuclear Structure of neutron-rich nuclei around N=40 *Silvia M. Lenzi* Contact email: *lenzi@pd.infn.it*
NS 126.	Spectroscopy of ^{26}F to probe proton-neutron forces close to the drip line *A.Lepailleur, O. Sorlin, L. Caceres, B. Bastin, C. Borcea, R. Borcea, B. A. Brown, L. Gaudefroy, S. Grévy, G. F. Grinyer, G. Hagen, M. Hjorth-Jensen, G. R. Jansen, O. Llidoo, F. Negoita, F. de Oliveira, M.-G. Porquet, F. Rotaru, M.-G. Saint-Laurent, D. Sohler, M. Stanoiu, and J.C. Thomas* Contact email: *lepailleur@ganil.fr*
NS 127.	Lifetime Measurements in ^{160}Gd *S. R. Lesher, A. Aprahamian, C. Casarella, B. P. Crider, I. Marsh, E. E. Peters, M. Smith, S. W. Yates* Contact email: *slesher@uwlax.edu*
NS 128.	Less-Empirical Nuclear Density Functionals from Low-Momentum Interactions *T. Lesinski* Contact email: *tlesinsk@fuw.edu.pl*
NS 129.	Nuclear charge-exchange excitations in localized covariant density functional theory *H.Z. Liang, J. Meng, T. Nakatsukasa, Z.M. Niu, P. Ring, X. Roca-Maza, N. Van Giai, and P.W. Zhao* Contact email: *haozhao.liang@riken.jp*
NS 130.	The Orsay Universal Plunger System *J. Ljungvall, G. Georgiev* Contact email: *joa.ljungvall@csnsm.in2p3.fr*

NS 131.	Decay spectroscopy of exotic nuclei at RIBF *G. Lorusso, S. Nishimura, H. Baba, P. Boutachkov, F. Browne, P. Doornenbal, R. Gernhäuser, G. Gey, T. Isobe, H.S. Jung, A. Jungclaus, I. Kojouharov, N. Kurz, Y.K. Kwon, Z. Li, K. Moschner, M. Niikura, H. Nishibata, A. Odahara, H. Sakurai, H. Schaffner, G. Simpson, P.-A. Söderström, K. Steiger, T. Sumikama, J. Taprogge, Z. Vajta, H. Watanabe, V. Werner, J. Wu, Z. Xu, A. Yagi, K. Yoshinaga* Contact email: *lorusso@ribf.riken.jp*
NS 132.	Recent Experimental Studies of Nuclear Triaxiality in A~160 Region *W. C. Ma* Contact email: *mawc@ra.msstate.edu*
NS 133.	Survey and Evaluation of Isobaric Analogue States *M. MacCormick, G. Audi, A.H.Wapstra* Contact email: *maccorm@ipno.in2p3.fr*
NS 134.	Nuclei at the Edge of Chaos *G. Maino* Contact email: *giuseppe.maino@unibo.it*
NS 135.	Probing core polarization around ^{78}Ni: intermediate energy Coulomb excitation of ^{74}Ni *T. Marchi, G. de Angelis, T. Baugher, D. Bazin, J. Berryman, R. Clark, E. Crawford, M.Doncel, E. Farnea, A. Gade, A. Gadea, T. Glasmacher, A. Gottardo, F. Gramegna, S. McDaniel, C. Michelagnoli, D.R. Napoli, B. Quintana, A. Ratkiewicz, F. Recchia, E. Sahin, A. Shore, R. Stroberg, J.J. Valiente-Dobón, D. Weisshaar, K. Wimmer, R. Winkler* Contact email: *tommaso.marchi@lnl.infn.it*
NS 136.	Nuclear Tensor Force and Effective Pions in the Relativistic Hartree-Fock Formalism *S. Marcos, M. López-Quelle, R. Niembro, L. N. Savushkin* Contact email: *lopezqm@unican.es*
NS 137.	Nucleon size effects in the parity violating electron scattering asymmetry *J. R. Marinelli, C. A. Graeff* Contact email: *ricardo@fsc.ufsc.br*
NS 138.	Ab initio calculations for ^{12}C with JISP16 *P. Maris, J.P. Vary, M.A. Caprio* Contact email: *pmaris@iastate.edu*

NS 139.	Gamow-Teller strength in deformed nuclei within self-consistent pnQRPA with the Gogny force *M. Martini, S. Péru, S. Goriely* Contact email: *martini.marco@gmail.com*
NS 140.	Change of radius of oxygen isotopes with an mechanism of enlarged core *H. Masui, K. Katō, K Ikeda* Contact email: *hgmasui@mail.kitami-it.ac.jp*
NS 141.	In-beam γ-ray spectroscopy of $^{38;40;42}$Si *M. Matsushita S. Takeuchi, N. Aoi, P. Doornenbal, J. Lee, K. Li, H. Scheit, D. Steppenbeck, H. Wang, K. Ieki, H. Baba, D. Bazin, L. Càceres, H. Crawford, P. Fallon, R. Gernhäuser, J. Gibelin, S. Go, S. Grévy, C. Hinke, C. R. Hoffman, R. Hughes, E. Ideguchi, D. Jenkins, N. Kobayashi, Y. Kondo, R. Krücken, T. Le Bleis, G. Lee, A. Matta, S. Michimasa, T. Motobayashi, T. Nakamura, S. Ota, M. Petri, T. Sako, H. Sakurai, S. Shimoura, K. Steiger, K. Takahashi, M. Takechi, Y. Togano, R. Winkler, K. Yoneda* Contact email: *matsushi@cns.s.u-tokyo.ac.jp*
NS 142.	Nuclear pairing from realistic forces: singlet channels and higher partial waves *S. Maurizio, J.W. Holt, P. Finelli* Contact email: *paolo.finelli@bo.infn.it*
NS 143.	Proton inelastic scattering study on ^{30}Ne and ^{34,36}Mg isotopes *S. Michimasa, Y. Yanagisawa, K. Inafuku, N. Aoi, Z. Elekes, Zs. Fülöp, Y.Ichikawa, N.Iwasa, K. Kurita, M. Kurokawa, T. Machida, T. Motobayashi, T. Nakamura, T. Nakabayashi, M. Notani, H. J. Ong, T. K. Onishi, H. Otsu, H. Sakurai, M. Shinohara, T. Sumikama, S. Takeuchi, K. Tanaka, Y. Togano, K. Yamada, M. Yamaguchi, K. Yoneda* Contact email: *mitimasa@cns.s.u-tokyo.ac.jp*
NS 144.	Direct mapping of shell effects in the heaviest elements *E. Minaya Ramirez, D. Ackermann, K. Blaum, M. Block, C. Droese, Ch. E.Düllmann, M. Eibach, S. Eliseev, E. Haettner, F. Herfurth, F.P. Heßberger, S.Hofmann, G. Marx, D. Nesterenko, Yu.N. Novikov, W.R. Plaß, D. Rodríguez, C.Scheidenberger, L. Schweikhard, P.G. Thirolf and C. Weber* Contact email: *E.Minaya@gsi.de*
NS 145.	Systematics of band moment of inertia of yrast and excited SD bands of even-even nuclei in A=150 mass region *H.M. Mittal and Neha Sharma* Contact email: *mittal.hm@lycos.com*
NS 146.	Collectivity in neutron-rich Co and Mn isotopes going towards N = 40 *V. Modamio* Contact email: *victor.modamio@lnl.infn.it*

NS 147.	Effect of the isoscalar and isovector pairing-strengths on the system energy of even-even nuclear systems *D. Mokhtari, N.H. Allal and M. Fellah* Contact email: *nallal@usthb.dz ; allaln@yahoo.com*
NS 148.	Laser spectroscopy - optical probes for radioactive nuclei *I.D. Moore, P. Campbell, B. Cheal, I. Pohjalainen, M. Reponen, V. Sonnenschein* Contact email: *iain.d.moore@jyu.fi*
NS 149.	^{72}Zn(d,^{3}He)^{71}Cu transfer reaction *P. Morfouace, S. Franchoo, M. Assié, F. Azaiez, D. Beaumel, S. Boissinot, R. Borcea, J.Burgunder, L. Caceres, N. De Séréville, Z. Dombradi, J. Elsevier, B. Fernandez Dominguez, A.Gillibert, S. Giron, S. Grévy, F. Hammache, O. Kamalou, V. Lapoux, L. Lefebvre, A. Lepailleur, C. Louchart, G. Marquinez, I. Martel Bravo, I. Matea, D. Mengoni, L. Nalpas, D. Napoli, M.Niikura, F. Recchia, A-M Sanchez Benitez, J-A. Scarpaci, D. Sohler, O. Sorlin, M.Stanoiu, I.Stefan, C. Stodel, J-C. Thomas, Z. Vajta* Contact email: *morfouac@ipno.in2p3.fr*
NS 150.	Giant Dipole Resonance in ^{28}Si+^{116}Cd reaction *Ish Mukul, A. Roy, P. Sugathan, Gayatri Mohanto, Jagdish Gehlot, Rakesh Dubey, N. Madhavan, S. Nath, Indranil Mazumdar, D.A. Gothe, Maninder Kaur, A. K. Rhine Kumar, P. Arumugam* Contact email*: ishmukul@gmail.com*
NS 151.	Two-neutron-transfer to ^{178}Yb and Population of ^{178m2}Hf via Incomplete Fusion *S.M. Mullins, B.G. Maqabuka, R.A.Bark, S. Bogolomov, S. H. Connell, A Efremov, I. Kuti, E.A.Lawrie, J.J. Lawrie, S.N.T. Majola, J. Molnár, S.H.T. Murray, B. Nyakó, P.Papka, R. Thomae* Contact email: *smm@tlabs.ac.za*
NS 152.	Kinematically complete measurements of Coulomb breakup of Borromean halo nuclei at the SAMURAI facility at RIBF *T. Nakamura, R. Minakata, S. Ogoshi, Y. Kondo, R. Tanaka, T. Kobayashi, N.A. Orr, H. Otsu, K. Yoneda, T. Isobe, N. Kobayashi, N.L. Achouri, T. Aumann, H. Baba, F. Delaunay, P. Doornenbal, N. Fukuda, J. Gibelin, Jong Won Hwang, N. Inabe, M. Ishihara, D. Kanno, D. Kameda, S. Kim, T. Kubo, S. Leblond, J. Lee, F.M. Marqués, T. Motobayashi, D. Murai, T. Murakami, K. Muto, T. Nakashima, N. Nakatsuka, S. Nishi, A. Navin, H. Sato, Y. Satou, Y. Shimizu, H. Suzuki, K. Takahashi, H. Takeda, S. Takeuchi, Y. Togano, A.G. Tuff, M. Vanderbrouck* Contact email: *nakamura@phys.titech.ac.jp*
NS 153.	Spectroscopy of ^{98}Ru *A. Nannini, A. Perego, P. Sona* Contact email: *nannini@fi.infn.it*

NS 154.	g factor measurement of the 2_1^+ state in ^{138}Ce using Recoil Into Vacuum *F. Naqvi, V. Werner, T. Ahn, G. Ilie, N. Cooper, D. Radeck, M. P. Carpenter, C. J. Chiara, F.Kondev, T. Lauritsen, C. J. Lister, D. Seweryniak, S. Zhu* Contact email: *farheen.naqvi@yale.edu*
NS 155.	Critical analysis of the pygmy giant resonance nature: the crossover with the vortical toroidal flow *V.O. Nesterenko, P.-G. Reinhard, J. Kvasil, and A. Repko* Contact email: *nester@theor.jinr.ru*
NS 156.	First observation of an isomeric state in proton drip-line nucleus ^{26}P *D. Nishimura, M. Fukuda, T. Sakai, M. Tanaka, K.Abe, J. Chiba, S. Fukuda, H. Furuki, A. Honma, H. Hotaka, N. Ichihashi, N. Inaba, K. Iwamoto, T. Izumikawa, Y. Kamisho, K. Kanbe, N. Kikukawa, A. Kitagawa, J. Kouno, M. Nagashima, Y. Nakamura, I. Nishizuka, M. Mihara, S. Miyazawa, Y. Morita, J. Ono, T. Ohtsubo, K. Sato, S. Sato, D. Sera, S. Suzuki, S. Suzuki, T. Suzuki, M. Takechi, K. Tashiro, M. Wakabayashi, D. Watanabe, M. Yaguchi, T. Yamaguchi, S. Yamaki, S. Yasumoto, K. Yoshinaga, and Y. Zhu* Contact email: *dnishimura@rs.tus.ac.jp*
NS 157.	Decay spectroscopy of very neutron-rich nuclei at RIBF *S. Nishimura, H. Baba, P. Boutachkov, F. Browne, P. Doornenbal, R. Gernhäuser, G. Gey, T. Isobe, H.S. Jung, A. Jungclaus, I. Kojouharov, N. Kurz, Y.K. Kwon, Z. Li, G. Lorusso, K. Moschner, M. Niikura, H. Nishibata, A. Odahara, H. Sakurai, H. Schaffner, T. Shimoda, G. Simpson, P.-A. Söderström, K. Steiger, T. Sumikama, J. Taprogge, Z. Vajta, H. Watanabe, J. Wu, Z. Xu, A. Yagi, K. Yoshinaga, V. Werner* Contact email: *nishimu@ribf.riken.jp*
NS 158.	Study of the properties of the superheavy nucleus Z = 117 produced in the ^{249}Bk + ^{48}Ca reaction *Yu.Ts. Oganessian, F.Sh. Abdullin, C. Alexander, J. Binder, R.A. Boll, S.N. Dmitriev, J. Ezold, K. Felker, J.M. Gostic, R.K. Grzywacz, J.H. Hamilton, R.A. Henderson, M.G. Itkis, K. Miernik, D. Miller, K.J. Moody, A.N. Polyakov, A.V. Ramayya, J.B. Roberto, M.A. Ryabinin, K.P. Rykaczewski, R.N. Sagaidak, D.A. Shaughnessy, I.V. Shirokovsky, M.V. Shumeiko, M.A. Stoyer, N.J. Stoyer, V.G. Subbotin, A.M. Sukhov, Yu.S. Tsyganov, V.K. Utyonkov, A.A. Voinov, and G.K. Vostokin* Contact email: *voinov_2000@mail.ru*
NS 159.	Extended Brueckner-Hartree-Fock theory and importance of pions in nuclei *Y. Ogawa, H. Toki* Contact email: *ogaway@rcnp.osaka-u.ac.jp*
NS 160.	Rotational band in ^{12}C based on the Hoyle state *A.A. Ogloblin, A.S. Demyanova, A.N. Danilov, S.V. Dmitriev, T.L. Belyaeva, S.A. Goncharov, V.N. Maslov, Yu.G. Sobolev, W. Trzaska, S.V. Khlebnikov* Contact email: *ogloblina@bk.ru*

NS 161.	New Pfaffian formulae for an overlap of multiple quasiparticle states *Makito Oi, Takahiro Mizusaki* Contact email: *m.oi@isc.senshu-u.ac.jp*
NS 162.	Triaxial deformation and nuclear shape transition in ^{192}Au *Y. Oktem, D. L. Balabanski, B. Akkus, L. Amon Susam, L. Atanasova, C. W. Beausang, R. B. Cakirli, R. F. Casten, M. Danchev, M. Djongolov, E. Ganioglu, K. A. Gladnishki, J. Tm. Goon, D. J. Hartley, A. A. Hecht, R. Krücken, J. R. Novak, G. Rainovski, L. L. Riedinger, T. Venkova, I. Yigitoglu, N. V. Zamfir, and O. Zeidan* Contact email: *sgyks@istanbul.edu.tr*
NS 163.	First β-decay study of ^{66}Mn into ^{66}Fe *B. Olaizola, L.M. Fraile, H. Mach, J.A. Briz, J. Cal-González, D. Ghita, U. Köster, W. Kurcewicz, S.R. Lesher, D. Pauwels, E. Picado, A. Poves, D. Radulov, G. Simpson, J.M. Udias* Contact email: *olaizola@nuclear.fis.ucm.es*
NS 164.	Evidence of tensor interactions in ^{16}O observed via (p,d) reaction *H. J. Ong, I. Tanihata, A. Tamii, T. Myo, K. Ogata, M. Fukuda, K. Hirota, K. Ikeda, D.Ishikawa, T. Kawabata, H. Matsubara, K. Matsuta, M. Mihara, T. Naito, D. Nishimura, Y.Ogawa, H. Okamura, A. Ozawa, D. Y. Pang, H.Sakaguchi, K. Sekiguchi, T. Suzuki, M.Taniguchi, M. Takashina, H. Toki, Y. Yasuda, M. Yosoi, J. Zenihiro* Contact email: *onghjin@rcnp.osaka-u.ac.jp*
NS 165.	Neutron single-particle energies near ^{78}Ni: low-lying states in ^{79}Zn studied via single-nucleon transfer *R. Orlandi, D. Mücher, G. de Angelis, J. Johansen, A. Jungclaus, S. D. Pain, R. Raabe, A. Andreyev, V. Bildstein, R. Chapman, T. E. Cocolios, J. Diriken, J. Elseviers, R. Gernhäuser, A. Gottardo, M. Huyse, T. Kröll, R. Krücken, J. Lane, V. Liberati, K. Nowak, J. Pakarinen, F. Recchia, P. Reiter, T. Roger, E. Sahin, J. F. Smith, J. J. Valiente Dobón, P. Van Duppen, M. von Schmidt, N. Warr, K. Wimmer* Contact email: *Riccardo.Orlandi@fys.kuleuven.be*
NS 166.	Beta Decay of Exotic T_Z = -1, -2 Nuclei: the Interesting Case of ^{56}Zn *S.E.A. Orrigo, B. Rubio, Y. Fujita, B. Blank, W. Gelletly, J. Agramunt, A. Algora, P. Ascher, B. Bilgier, L. Cáceres, R.B. Cakirli, H. Fujita, E. Ganioğlu, M. Gerbaux, J. Giovinazzo, S. Grévy, O. Kamalou, H.C. Kozer, L. Kucuk, T. Kurtukian-Nieto, F. Molina, L. Popescu, A.M. Rogers, G. Susoy, C. Stodel, T. Suzuki, A. Tamii, J.C. Thomas* Contact email: *orrigo@ific.uv.es*
NS 167.	Probing the neutron skin thickness in collective modes of excitation *N. Paar* Contact email: *npaar@phy.hr*

NS 168.	Identification of intruder $\pi i_{13/2}$ state in ^{197}Tl *H. Pai, G. Mukherjee, S. Bhattacharya, C. Bhattacharya, S. Bhattacharyya, T. Bhattacharjee, S. Chanda, M.R. Gohil, S. Kundu, T.K. Ghosh, K. Banerjee, T.K. Rana, R. Pandey, G. Prajapati, S. Rajbanshi, A. Goswami, S. Mukhopadhyay, D. Pandit, S. Pal, S. R. Banerjee, J. K. Meena, P. Mukhopadhyay, A. Chawdhury, and P. Chawdhury* Contact email: *gopal@vecc.gov.in*
NS 169.	Non-adiabatic description of proton emission from the odd-odd nucleus ^{130}Eu *Monika Patial, P. Arumugam, A. K. Jain, E. Maglione, L. S. Ferreira* Contact email: *monikaphd@gmail.com*
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NS 173.	Low-lying bands with different quadrupole deformation in ^{155}Dy *P. Petkov, M.S. Yavahchova , O. Moller, A. Dewald, B. Saha, A. Fitzler, K. Jessen, D.Tonev, T. Klug, S. Heinze, J. Jolie, P. von Brentano, N. Goutev, D. Bazzacco, C. A. Ur, E.Farnea, M. Axiotis, S. Lunardi, G. de Angelis, D. R. Napoli, N. Marginean, T. Martinez and M. A. Caprio* Contact email: *m.yavahchova@gmail.com*
NS 174.	Exotic rotations and seniority isomers in Nd nuclei *C. M. Petrache* Contact email*: petrachel@csnsm.in2p3.fr*
NS 175.	Combining γ and particle spectroscopy in Cologne *S. G. Pickstone, V. Derya, J. Endres, A. Hennig, J. Mayer, L. Netterdon, S. Pascu, A. Sauerwein, P. Scholz, M. Spieker, T.-M. Streit, and A. Zilges* Contact email: *pickstone@ikp.uni-koeln.de*
NS 176.	On the Road to FAIR: First Operation of AGATA in PreSPEC at GSI *N.Pietralla* Contact email: *pietralla@ikp.tu-darmstadt.de*

NS 177.	Isomers in heavy nuclei: structure and projectile fragmentation studies *Zsolt Podolyák* Contact email: *z.podolyak@surrey.ac.uk*
NS 178.	The three shapes of ^{32}Mg *A.Poves, F. Nowacki* Contact email: *alfredo.poves@uam.es*
NS 179.	Nuclear structure study of ^{106}Pd and ^{106}Cd with the $(n,n'\gamma)$ reaction *F.M. Prados-Estévez, A. Chakraborty, E.E. Peters, M.G. Mynk, A. Linnemann, D. Bandyopadhyay, N. Boukharouba, S.N. Choudry, B.P. Crider, P.E. Garrett, S. F. Hicks, J. Jolie, A. Kumar, S. R. Lesher, C.J. McKay, M.T. McEllistrem, S. Mukhopadhyay, J.N. Orce, M. Scheck, J.R. Vanhoy, J.L. Wood, and S.W. Yates* Contact email: *francisco.prados-estevez@uky.edu*
NS 180.	Normal and Superdeformed Band Structures of ^{105}Ag *C.R. Praharaj, Z. Naik* Contact email: *crp@iopb.res.in*
NS 181.	Microscopic approach to the structure of superheavy nuclei *V.Prassa, Bing-Nan Lu, T. Nikšić, D. Vretenar* Contact email: *bpras@physics.auth.gr*
NS 182.	The structure of nuclei around ^{100}Sn: A simple shell model description *Chong Qi* Contact email: *chongq@kth.se*
NS 183.	Nuclear structure of the heavy iron isotopes in the vicinity of ^{68}Ni *D. Radulov, D. Pauwels, I. Darby, H. De Witte, J. Diriken, D.V. Fedorov, V.N.Fedosseev, L.M. Fraille, M. Huyse, U. Köster, B.A. Marsh, L.A. Popescu, M.D. Seliverstov, A.M.Sjödin, J. Van de Walle, P. Van de Bergh, P. Van Duppen, M. Venhart, W.B. Walters, K.Wimmer* Contact email: *deyan.radulov@fys.kuleuven.be*
NS 184.	Application of the sextic oscillator potential together with Mathieu and spheroidal functions for triaxial and X(5) type nuclei *A. A. Raduta and P. Buganu* Contact email: *raduta@nipne.ro, buganu@theory.nipne.ro*
NS 185.	Terminating bands observed to new heights of spin and excitation energy *I. Ragnarsson, B.G. Carlsson, Hai-Liang Ma, A. Kardan, Purnima Singh, S. Nag, A.K. Singh, H. Hübel* Contact email: *ingemar.ragnarsson@matfys.lth.se*

NS 186.	Direct evidence of ground state wave-function of neutron-rich ^{30}Na isotope through Coulomb Breakup *A.Rahaman, U. Datta Pramanik, T. Aumann, S. Beceiro, T. Le Bleis, K. Boretzky, D. Cotrina-Gil, C. Caesar, S. Chakraborty, M. Chariter, W. N. Catford, D. Gonzalez-Diaz, H. Emling, P. Diaz-Fernandez, Y. Dimitry, L. M. Fraile, G. De Angelis, O. Ershova, H. Geissel, M. Heil, M. Heine, T. Heftrich, B. Jonson, A. Kelic, H. Johansson, R. Krucken, T. Kroll, C. Langer, Y. Leiffel, G. Munzenberg, A. Movsesyan, J. Marganiec, C. Nociforo, A. Najafi, V. Panin, R. Plag, H. A. Pol, S. Paschalis, R. Reifarth, D. Rossi, J. Ray, G. Rastrepina, H. Simon, C. Scheidenberger, S. Typel, J. Taylor, Y. Togano, E. Uberseder, V. Volkov, H. Weick, A.Wagner, F. Wamers, M. Weigand, J. Winfield, M. Zoric* Contact email: *ushasi.dattapramanik@saha.ac.in*
NS 187.	Non-axial study of some even-even actinide nuclei with octupole-octupole interaction *Daya Ram, Saiqa Sadiq, Rani Devi and S.K. Khosa* Contact email: *daya.kamal123@gmail.com*
NS 188.	Investigation of the E2 and E3 matrix elements in ^{200}Hg using inelastic scattering *E. T. Rand, G. C. Ball, V. Bildstein, T. Faestermann, P. E. Garrett, B. Hadinia, R. Hertenberger, D. S. Jamieson, B. Jigmeddorj, K. G. Leach, C. E. Svensson, H.-F. Wirth* Contact email: *erand@uoguelph.ca*
NS 189.	The observation of a strong E0 component in the $2_2^+ \rightarrow 2_1^+$ transition in ^{184}Hg from the β-decay of laser-ionized thallium isotopes: a strong signature for shape coexistence *E. Rapisarda* Contact email: *elisa.rapisarda@cern.ch*
NS 190.	Exotic decay of hot rotating nuclei near proton drip line *J. Ray, U. Datta Pramanik, R. K. Bhowmik, S. Chakraborty, A. Chakraborty, R. Garg, S. Goyal, S. Ganguly, S. Kumar, S. Mandal, B. Mukherjee, P. Mukherjee, S. Muralithar, D. Negi, A. Rahaman, I. Ray, M. Saxena, K. Selvakumar, P. Singh, A. K. Singh, and R. P. Singh* Contact email: *ushasi.dattapramanik@saha.ac.in*
NS 191.	Single-Particle Strength in the Odd, Neutron-Rich Ni Isotopes *F. Recchia, A. Gade, R.V.F. Janssens, D. Weisshaar, M. Albers, V. Bader, T. Baugher, D. Bazin, J. Berryman, C.M. Campbell, M.P. Carpenter, J. Chen, C.J. Chiara, H. Crawford, C.R. Hoffman, F.G. Kondev, A. Korichi, C. Langer, T. Lauritsen, E. Lunderberg, S. Noji, R. Stroberg, S. Williams, K. Wimmer, S. Zhu* Contact email: *recchia@nscl.msu.edu*

NS 192.	The onset of triaxiality in neutron-rich rhenium isotopes *M.W. Reed, G.J. Lane, G.D. Dracoulis, A.P. Byrne,H. Watanabe, R.O. Hughes, F.G. Kondev, M. P. Carpenter, R.V.F. Janssens, T. Lauritsen, C.J. Lister, D. Seweryniak, S. Zhu, P. Chowdhury* Contact email: *matthew.reed@anu.edu.au*
NS 193.	Beta decay to continuum states *K. Riisager* Contact email: *kvr@phys.au.dk*
NS 194.	Decay of the high-K isomer in the Z=104 nucleus ^{257}Rf *J. Rissanen, R. M. Clark, K. Gregorich, J. Gates, C. M. Campbell, H. Crawford, M. Cromaz, N. Esker, P. Fallon, U. Forsberg, O. Gothe, I. -Y. Lee, H.L. Liu, A. O. Macchiavelli, P. Mudder, H. Nitsche, G. Pang, A. Rice, M.A. Stoyer, A. Wiens, and F.R. Xu* Contact email: *juhorissanen@lbl.gov*
NS 195.	Lifetime studies of ^{133}Cs *O.J.Roberts, A.M.Bruce, F.Browne, N. Mărginean, T.Alharbi, T. Alexander, L.M. Fraile, D. Ivanova, S. Kisyov, P.J.R. Mason, K. Mulholland, P.H. Regan, P-A. Söderström, C.M. Townsley, B. Olaziola, J.F. Smith* Contact email: *O.J.Roberts@brighton.ac.uk*
NS 196.	Octupole correlations from a theoretical perspective *Luis M. Robledo* Contact email: *luis.robledo@uam.es*
NS 197.	The Nuclear Symmetry Energy: constraints from Giant Resonances and Parity Violating Electron Scattering *X. Roca-Maza, B. K. Agrawal, P. F. Bortignon, M. Brenna, Li-Gang Cao, M. Centelles, G. Colò, N. Paar, X. Viñas, D. Vretenar and M. Warda* Contact email: *xavier.roca.maza@mi.infn.it*
NS 198.	Alpha Cluster Structure in ^{16}O *M.R.D. Rodrigues, T. Borello-Lewin, H. Miyake, F. Cappuzzello, M. Cavallaro, J.L.M. Duarte, C.L. Rodrigues, M.A. Souza, L.B. Horodynski-Matsushigue, C. Agodi, M. Bondì, D. Carbone, A. Cunsolo, A. Foti, D. Nicolosi, S.Tropea, G.M. Ukita, P.N. de Faria* Contact email: *marciadr@if.usp.br*
NS 199.	Extending the knowledge of neutron-rich nuclides by precision mass measurements with ISOLTRAP *M. Rosenbusch, D. Atanasov, D. Beck, K. Blaum, Ch. Böhm, Ch. Borgmann, M.Breitenfeldt, R. B. Cakirli, T. E. Cocolios, S. Eliseev, S. George, F. Herfurth, A. Herlert, M. Kowalska, S.Kreim, Y. Litvinov, D. Lunney, V. Manea, E. Minaya Ramirez, S. Naimi, D. Neidherr, L.Schweikhard, J. Stanja, F. Wienholtz, R. N. Wolf, K. Zuber* Contact email: *rosenbusch@uni-greifswald.de*

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NS 245.	Prompt γ-ray spectroscopy of neutron rich cadmium isotopes in the vicinity of ^{132}Sn *A. Vancraeyenest, G.S. Simpson, G. Gey, F. Drouet, G. Kessedjian, T. Malkiewicz, M. Ramdhane, C. Sage, G. Thiamova, T. Grahn, P.T. Greenlees, K. Hauschild, A. Herzan, U. Jakobsson, P. Jones, R. Julin, S. Juutinen, S. Ketelhut, A. Lopez-Martens, P. Nieminen, P. Peura, P. Rahkila, S. Rinta-Antila, P. Ruotsalainen, M. Sandzelius, J. Saren, C. Scholey, J. Sorri, J. Uusitalo* Contact email: *aurelie.vancraeyenest@lpsc.in2p3.fr*
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NS 251.	Beta-decay study of the r-process nucleosynthesis nucleus, ^{102}Rb, at TRIUMF-ISAC *Z. -M. Wang, A. B. Garnsworthy, C. Andreoiu, G. C. Ball, P. C. Bender, A. Bey, V. Bildstein, D. S. Cross, G. Demand, R. Dunlop, L. Evitts, P. E. Garrett, G. Hackman, B. Hadinia, S. Ketelhut, R. Krücken, A. Laffoley, K. Leach, D. Miller, J. Pore, A. Radich, M. M. Rajabali, C. E. Svensson, E. Tardiff, C. Unsworth, A. Voss, P. Voss* Contact email: *zmwang@triumf.ca*
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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Monte Carlo shell model towards *ab initio* nuclear structure

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One of the major challenges in nuclear physics is to describe nuclear structure and reactions from *ab initio* calculations with nuclear forces based on nucleon degrees of freedom. Such calculations have recently become feasible for nuclear many-body systems beyond $A = 4$ due to the rapid evolution of computational technologies. Together with the Green's Function Monte Carlo and Coupled Cluster Theory, the No-Core Shell Model (NCSM) is one of the relevant *ab initio* methods and is now available for the study of nuclear structure and reactions in the p-shell nuclei. As the NCSM treats all the nucleons democratically, computational demands for the calculations explode exponentially as the number of nucleons increases. Current computational resources limit the direct diagonalization of the Hamiltonian matrix using the Lanczos algorithm to basis spaces with a dimension of around 10^{10}. In order to access heavier nuclei beyond the p-shell region with larger basis dimensions, many efforts have been devoted to the NCSM calculations. One of these approaches is the Importance-Truncated NCSM where the basis spaces are extended by using an importance measure evaluated using perturbation theory. Another approach is the Symmetry-Adapted NCSM where the basis spaces are truncated by the selected symmetry groups. Similar to these attempts, the no-core Monte Carlo Shell Model (MCSM) [1,2] is one of the promising candidates to go beyond the Full Configuration Interaction (FCI) method which is a different truncation of the basis states that commonly used in the NCSM. Here, we report recent developments of the MCSM and its application to the no-core calculations [1]. It is shown that recent developments enable us to apply the MCSM to the shell-model calculations without a core. Benchmarks between the MCSM and FCI methods demonstrate consistent results with each other within estimated uncertainties. No-Core Full Configuration (NCFC) results are also presented as full *ab initio* solutions extrapolated to the infinite basis limit.

This work was supported in part by the SPIRE Field 5 from MEXT, Japan. We also acknowledge Grants-in-Aid for Young Scientists (Nos. 20740127 and 21740204), for Scientific Research (Nos. 20244022 and 23244049), and for Scientific Research on Innovative Areas (No. 20105003) from JSPS, and the CNS-RIKEN joint project for large-scale nuclear structure calculations. This work was also supported in part by the US DOE Grants No. DE-FC02-07ER41457, DE-FC02-09ER41582 (UNEDF SciDAC Collaboration), and DE-FG02-87ER40371, by US NSF grand 0904782, and through JUSTIPEN under grant no. DE-FG02-06ER41407. A part of the MCSM calculations was performed on the T2K Open Supercomputer at the University of Tokyo and University of Tsukuba, and the BX900 Supercomputer at JAEA. Computational resources for the FCI and NCFC calculations were provided by the National Energy Research Supercomputer Center (NERSC), which is supported by the Office of Science of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231, and by the Oak Ridge Leadership Computing Facility at the Oak Ridge National Laboratory, which is supported by the Office of Science of the U.S. Department of Energy under Contract No. DE-AC05-00OR22725.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Spectroscopic properties of actinides and light superheavy nuclei in covariant density functional theory.

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The questions of the existence limits and the properties of shell-stabilized superheavy nuclei have been a driving force behind experimental and theoretical efforts to investigate the spectroscopy of the heaviest nuclei. Unfortunately, theoretical predictions for superheavy nuclei on the location of the island of stability and some other physical observables (such as fission barriers) differ considerably. In such a situation the errors of theoretical approaches have to be estimated. Actinides and light superheavy nuclei, for which spectroscopic data are available, play a role of testing ground for that. The comprehensive analysis of different physical observables related to (i) single-particle states [1], (ii) pairing properties [2], (iii) rotational response [2] and (iv) fission properties [3] of these nuclei has been performed within covariant density functional theory (CDFT) [4]. The goal of this analysis is twofold. First, to understand the strengths and weaknesses of the CDFT with respect of the description of these physical observables and to define the directions of its improvement. Second, to define the accuracy of the description of different physical observables using *all available* experimental data and to understand the reliability of the extrapolation to superheavy nuclei.

The main emphasis of this presentation is on the studies of pairing, single-particle, and rotational properties within the cranked relativistic Hartree-Bogoliubov (CRHB) theory. Extensive studies of odd-even mass staggerings (via three-point $\Delta^{(3)}$ indicators) has been performed for the first time in the CDFT framework [2]. They show that contrary to lighter nuclei the strength of the D1S Gogny force in the particle-particle channel of the CRHB+LN theory has to be attenuated in actinides by $\approx 10\%$. Similar attenuation is also needed for a proper description of the moments of inertia [2]; with this attenuation the absolute values and the evolution of the moments of inertia with spin and particle number are well described in even-even nuclei. Thus, the definitions of pairing strength via these two observables correlate; this is non-trivial result in the DFT framework since time-odd mean fields (absent in phenomenological models) strongly affect the moments of inertia and have an impact on the $\Delta^{(3)}$ indicators.

For the first time a systematic analysis of the accuracy of the description of the energies of one-quasiparticle configurations in deformed odd nuclei has been performed in the DFT framework in [1]. It provides theoretical estimates on the errors in calculated energies of one-quasiparticle configurations. Two sources of inaccuracies, namely, low effective mass leading to a stretching of the energy scale and incorrect relative positions of some single-particle states exist in model calculations. The analysis suggests that particle-vibration coupling has to be taken into account to improve the accuracy of the description of the energies of one-quasiparticle states. Despite these inaccuracies many aspects of the single-particle and collective motion are well described at the DFT level. For example, the observed sharp band crossings in the $A \geq 242$ nuclei [which are sensitive to the positions of high-j orbitals] as well as the rotational properties (both in magnitude and in respect of even-even nuclei) of odd-mass nuclei are well described in the CRHB+LN calculations [2]. The description of fission barriers is also not affected considerably by these inaccuracies [3].

This work has been supported by the U.S. Department of Energy under the grant DE-FG02-07ER41459.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Gamma-neutron competition above the neutron separation energy in delayed neutron emitters

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In neutron rich nuclei with sufficient neutron excess beta decay can proceed to states above the neutron separation energy in the daughter nucleus, which are unstable against neutron emission, leading to the well-known phenomenon of delayed neutron emission. The neutron width of the resonant states is expected to be much larger than the gamma width, and usually it is assumed that the gamma-ray emission is negligible. This is usually the case for estimations of the neutron emission probability based on theoretical calculations of the beta strength distribution [1].

Experimentally the information on gamma-neutron competition after beta decay is scarce [2,3]. This is due to the fact that the decay populates a region of high excitation energy and high level density and the consequent difficulty to detect the electromagnetic de-excitation with conventional high-resolution spectroscopy using HPGe. Gamma-neutron competition above the neutron separation energy is readily measured in neutron capture reactions but this information is restricted to nuclei close to the stability for which stable targets can be produced. Far from stability Total Absorption Gamma-ray Spectroscopy (TAGS) with 4π scintillation detectors applied to beta-decay studies [4] offers a unique opportunity to access experimentally this information, because of its high sensitivity to weak decay branches. Gamma and neutron widths carry important nuclear structure information as they depend on spin-parity distribution of levels in the daughter and the final nucleus. They also shape the delayed neutron energy spectrum [5].

Recently we have performed an experiment using the TAGS technique to investigate the beta-decay of some well known delayed neutron emitters with the purpose of determining the fraction of beta intensity to states above the neutron separation energy proceeding by gamma-ray de-excitation. The measurement was performed at the IGISOL-JYFL (Finland) mass separator, with radioactive beams purified by the Penning trap. The result shows a significant gamma branching ratio for those levels. The technical issues of this measurement and the results will be presented.

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Measurement of β-decay half-lives and delayed neutrons beyond the $N = 126$ shell closure

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Neutron shell closures play a fundamental role in nuclear structure and hence, in the formation of the heaviest elements by the so-called rapid neutron capture process. Despite its relevance, the experimental information available in the neutron rich region around N$\sim$126 is very scarce on both sides of the shell closure [1,2] due to the difficulty to access these nuclei, and the challenging experimental conditions. Theoretical models show large discrepancies [3,4], and an alarming discrepant trend is observed between theory and experimental data, which clearly calls for new experimental results in this mass region. This contribution reports new results on half-lives of several neutron rich nuclei ($N > 126$) of Au, Hg, Tl, Pb and Bi. In addition, we report beta-delayed neutron emission probabilities for several nuclei, the first ever measured in this mass region. The experiment was carried out at GSI, Darmstadt (Germany) using a high intensity (2×10^9 ions/s) and high energy (1 GeV/u) ^{238}U-beam. The FRS fragment separator was used to select the isotopes of interest, which were implanted in a stack of double-sided silicon strip detectors (SIMBA). The latter were surrounded by the high-efficiency BEta deLayEd Neutron detector in its 30 counters configuration (BELEN-30), which allowed to detect neutrons with an efficiency of about 40%.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Impact of nuclear structure on production and identification of superheavy nuclei

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The calculations performed with the modified two-center shell model reveal quite strong shell effects at $Z = 120 - 126$ and $N = 184$ [1]. So, our microscopic-macroscopic treatment qualitatively leads to the results close to those in the self-consistent mean-field treatments. If our prediction of the structure of heaviest nuclei is correct, than one can expect the production of evaporation residues $Z = 120$ in the reactions ^{50}Ti+^{249}Cf and ^{54}Cr+^{248}Cm with the cross sections 23 and 10 fb, respectively. The $Z = 120$ nuclei with $N = 175 - 179$ are expected to have Q_α about 12.1–11.2 MeV and lifetimes 1.7 ms–0.16 s in accordance with our predictions. These Q_α are in fair agreement with predictions of Liran et al. and about 2 MeV smaller than in other microscopic-macroscopic approaches. The experimental measurement of Q_α for at least one isotope of $Z = 120$ nucleus would help us to set proper shell model for the superheavies with $Z > 118$. Note that the definition of maxima of the excitation functions provides a good test for the predictions of the models as well.

Based on the calculated one-quasiproton spectra and energies for a decays, one can explain [2] why the α-decay chain of $^{291}117$ or $^{287}115$ is terminated by spontaneous fission of ^{267}Db. It is shown that, in the α-decay chain of $^{293}117$, the α decay of ^{281}Rg is hindered by the structure effects and because of this, the ^{281}Rg nucleus undergoes spontaneous fission instead of a decay. In addition, the number of isomeric states in the heaviest odd-Z nuclei is predicted. For the ^{282}Rg nucleus, we expect $T_\alpha \approx 25$ s and $T_{sf} \approx 110$ s, i.e., about ten times larger than for neighboring even-odd nuclei ^{283}Cn and ^{281}Ds. Thus, ^{282}Rg undergoes α decay.

Although the values of T_α found in the α-decay chains of ^{287}Fl and ^{293}Lv are quite large, one cannot completely exclude the α decays from the one-quasiparticle isomeric states in ^{287}Fl, ^{283}Cn, and ^{281}Ds [3]. For example, it is shown that the α decay of the ^{281}Ds nucleus occurs only from the ground state which can be populated with small probability in the α-decay chains of the ^{289}Fl element. The minimum of Q_α in ^{286}Fl indicates the neutron shell at $N = 172$. In other α-decay chains considered there is no minima of Q_α at $Z = 114$, which probably indicates the proton shell closure at $Z \geq 120$ as predicted with the self-consistent microscopic and microscopic-macroscopic [1] calculations.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

The 2012 Atomic Mass Evaluation and the Mass Tables

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From the famous formula $E = mc^2$, the nuclear masses yield their binding energies, i.e. the result of all interacting forces within the nucleus.

The Atomic Mass Tables are the fruit of the evaluation of all valid experimental data aiming at mass measurements, or in which relevant energy measurements are given.

Among the various projects that originated in the 1950s, the concept developed by Aaldert H. Wapstra, proved to be able to face the otherwise insolvable difficulties due to the strong interconnections among the measurements. This concept is the one that is referred to as the Atomic Mass Evaluation (AME). It was the only one which survived and produced a series of Mass Tables over the years, the most recent of those, in 1983, 1993, and 2003 (AME2003) [1], this last one already nine years ago.

A new Atomic Mass Table was eagerly awaited. It has just been released [2]. This new publication includes all experimental material that was available to us until the end of 2012: reaction and decay energy measurements, and inertial mass (spectrometers) mesurements; accepted and rejected experimental data, as well as outweighed ones

At the conference we will present the new policies and procedures used and also some of the most important features of our knowledge of the nuclear properties stemming from the experimental surface of masses as it appears nowadays: shell quenching at several magic numbers, new shells for the superheavies, the doubly-magic ^{270}Hs, recessing drip-lines,...

Among the co-authors of the AME2012 tables is the name of Aaldert H. Wapstra, the founder of the AME, who passed away at the end of 2006. He made essential contributions to the AME2012 during the two years following the publication of AME2003. And more than those two years, this work is filled with his work (back to the 1950's) and with his spirit.

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[3] Bulletins of the Amdc: http://amdc.in2p3.fr/bulletins/filel.html.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Cross sections of neutron removal reactions in the isotopic chain of ^{100}Sn

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The robustness of shell closures with isospin is the key to understand the shell structure away from stability. From this point of view, the region of ^{100}Sn (N = Z = 50) is of particular interest. The systematics of $B(E2;0^+_1\rightarrow 2^+_1)$ is shown to present a rather large collectivity for light Sn isotopes as compared to shell-model predictions (with a ^{100}Sn core).

We report here on the first results of an experiment performed at RIKEN in July 2012 for the production of ^{102}Sn by two-neutron removal reaction from ^{104}Sn. ^{104}Sn was produced and selected at the BigRIPS spectrometer from the interaction of a primary beam of ^{136}Xe at 350 MeV/A with a Be target. Then ^{104}Sn interacted at about 150 MeV/A with a secondary target to produce ^{102}Sn. The reaction products were identified by the Zero Degree Spectrometer (ZDS) whereas the secondary target is surrounded by the gamma detection setup DALI2 to perform the spectroscopy of the residual nuclei.

Two types of secondary targets were used: a carbon and a plastic target of CH_2. Inclusive neutron-removal cross sections from hydrogen and carbon will be discussed. The gamma spectroscopy obtained from one and two neutron removal to produce ^{103}Sn and ^{102}Sn will be presented. These first direct reaction measurements in the vicinity of ^{100}Sn will be compared to state-of-the-art Shell-Model + eikonal formalism predictions.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Lifetime measurements and high spin structure of ^{36}Cl nucleus

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Nuclei in the sd-shell are a fundamental testing ground for many basic models of nuclear structure. Several interesting phenomena can be studied as a function of the angular momentum in this mass region such as clusterization, shape coexistence, proton-neutron interaction, as well as the interplay between collective and single-particle motion. The ^{36}Cl nucleus, with one neutron and three proton valence holes with respect to the doubly magic ^{40}Ca, has been studied extensively in the past with the aim of elucidating the role of intruder particle-hole $sd-fp$ cross-shell configurations in the structure of sd-shell nuclei. In this work, excited states up to $J^{\pi}=11^{-}$ at 10296 keV and $J^{\pi}=10^{+}$ at 10707 keV have been populated in the odd-odd ^{36}Cl nucleus using the ^{24}Mg(^{14}N,2p) fusion-evaporation reaction at E_{lab} = 31 MeV. Twenty new states and 62 new γ-transitions have been identified by employing γ-γ and γ-γ-γ coincidences. Lifetimes have been investigated by the Doppler shift attenuation method. The experimental data have been compared with the results of large-scale shell model calculations performed using different effective interactions and model spaces allowing particle-hole excitations across the N=Z=20 shell gap.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Effects of the Skyrme Tensor Force on the Spin-Isospin Excitations

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Tensor force and its effects on nuclei attract much interest. The effects of the Skyrme tensor force on the ground state properties are widely studied, but it is still difficult to pin down the strengths of the tensor terms, even the sign. The effects of tensor force on the Gamow-Teller (GT) and charge-exchange Spin-Dipole (SD) states are studied by using the self-consisten HF+RPA calculation. For GT excitations, the energies of the main state and the low energy states can be affected dramatically[1]. For SD excitations, the tensor force produce a softening of 1- states, but a hardening of 0- and 2- states, so that to improve the agreement with experiment[2]. Inspired by these strong effects, we systematically studied GT and charge-exchange SD excitation energies in ^{90}Zr and ^{208}Pb to determine the appropriate magnitude of the tensor terms of the Skyrme interactions[3]. It is found that not all Skyrme interactions can meet the criteria $\delta E = |E_{\rm th} - E_{\rm exp}| \leqslant 2.5$ MeV for the centoid energy of GT and SD modes. Presently, many Skyrme interactions are studied systematically, only few of them can meet $\delta E \leqslant 2.5$ MeV, and even few of them such as Sly4 can meet the criteria $\delta E \leqslant 2$ MeV. It is found that when the tensor are added, for instance on top of SLy4, the charge-exchange modes can constrain rather well the value of the tensor-even strength, while the value of the tensor-odd strength is less constrained.

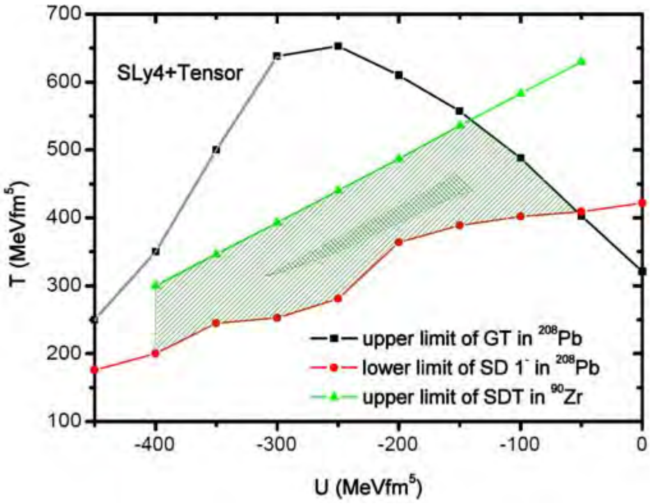

FIG. 1. The region of tensor-even and tensor-odd strengths T and U constrained by the criterion $\delta E \leqslant 2.5$ MeV (shaded region) and $\delta E \leqslant 2$MeV (double shaded region) for the GT and total SD centroid energies in ^{90}Zr and ^{208}Pb and for the SD 1^- centroid energy in ^{208}Pb. The tensor forces are added on top of SLy4 and used to calculate the centroid energies.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Three-Nucleon Forces in Exotic Open-Shell Isotopes

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As ab-initio calculations of atomic nuclei enter the A=40-100 mass range, a great challenge is how to provide accurate predictions for the vast majority of open-shell (degenerate) isotopes. Here we discuss advances in ab-initio calculations based on self-consistent Green's function theory. The method allows first principle calculations of truly open shell, semi-magic, nuclei and has been applied successfully up to ^{74}Ni with soft low-momenutm interactions [1,2]. By add realistic three-nucleon interactions to the state of the art Green’s function theory we find that physics of neutron driplines is reproduced with very good quality, see e.g. Fig 1 for the oxygen chain [3].

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 [2] and provides a theoretical optical potential for elastic scattering [4]. The talk will give examples of applications and discuss first results regarding the implication of three-nucleon forces on the evolution of correlations with proton-neutron asymmetry, with particular emphasis on neutron rich pf-shell isotopes.

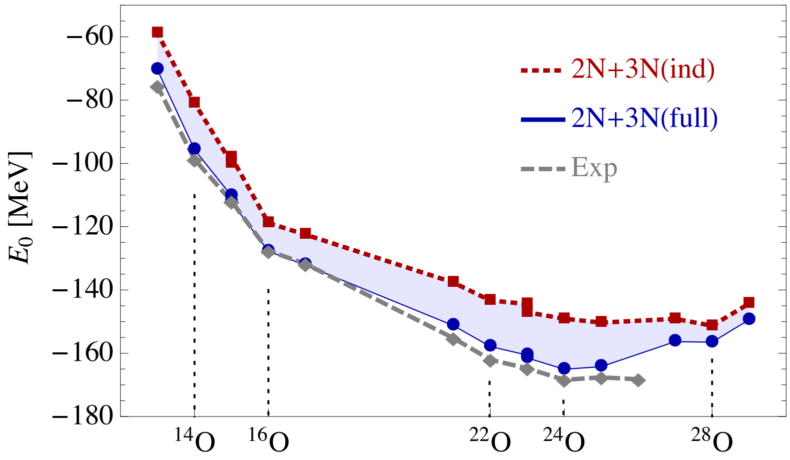

Figure 1: *Binding energies of oxygen isotopes predicted by SRG interactions evolved from chiral NN and 3NF [4].*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

The No Core Gamow Shell Model for ab-initio Nuclear Structure Calculations

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The *ab initio* No Core Shell Model (NCSM) is a microscopic approach for calculating the properties of atomic nuclei up to mass A $\approx$16, using any realistic NN (and NNN) interaction and treating all A nucleons as being active. Since its inception in the 1990s, it has had considerable success not only in explaining the binding and excitation energies and other properties of light atomic nuclei, but also in making predictions for properties not yet observed experimentally [1]. The NCSM calculations are usually performed utilizing a basis of harmonic-oscillator single-particle states, thus leading to well-bound states. With the recent advent of rare-isotope-beam accelerators, there is now considerable interest also in loosely-bound and unbound states, representing so-called open-quantum systems. To investigate such exotic nuclear states, we have adapted the Gamow Shell Model approach to the NCSM, which we call the No Core Gamow Shell Model (NCGSM). Our model is formulated in the rigged Hilbert space and employs a complete Berggren ensemble, allowing us to treat bound, resonant, and scattering states on an equal footing [2,3,4]. By including loosely bound states, we make the basis dimensional problem with increasing number of nucleons in the nucleus even more serious than in the NCSM. This difficulty can, however, be alleviated by using the Density Matrix Renormalization Group (DMRG) method to solve the many-body Schrödinger equation [5,6]. To test the validity of our approach, we first performed calculations for ^{3}H and ^{4}He and compared our results against exact Faddeev and Faddeev-Yakubovsky calculations, respectively. We will also present our results for the ground-state energy and decay width of the unstable nucleus ^{5}He, employing a realistic N^{3}LO interaction.

Acknowledgements: We acknowledge partial support of this work through FUSTIPEN (French-U.S. Theory Institute for Physics with Exotic Nuclei) under DOE grant number DE-FG02-10ER41700. Partial support of this work is also acknowledged by B.R.B. and G.P. through NSF grant number PHY-0854912 and by J.R. through the European Research Council under the European Community's Seventh Framework Programme (EP7/2007-2013)/ERC grant agreement no. 240603.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Shape coexistence and charge radii in thallium, gold and astatine isotopes studied by in-source laser spectroscopy at RILIS-ISOLDE

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The competition between spherical and deformed nuclear shapes at low energy gives rise to shape coexistence in the region of the neutron-deficient lead isotopes [1]. In order to determine to which extent the ground and/or isomeric states of those and neighboring nuclides are affected by this phenomenon, a campaign of investigation of changes in the mean-square charge radii and electromagnetic moments is on-going at ISOLDE. By combining the high sensitivity of the in-source laser spectroscopy technique, ISOLDE mass separation and Windmill alpha-decay spectroscopy setup [2], it has been possible to study long isotopic chains of lead [3] and polonium [4], down to N=100 and N=107 respectively, and, recently, thallium isotopic chain down to N=98.

In this contribution, we present the the preliminary results of the charge radii, electromagnetic moments and spins measurements in thallium, gold and astatine isotopes. In the gold and astatine cases, next to Faraday cup and Windmill measurements, also the Multi-Reflection Time-of-Flight (MR-ToF) mass separation technique [5] involving the ISOLTRAP collaboration was used.

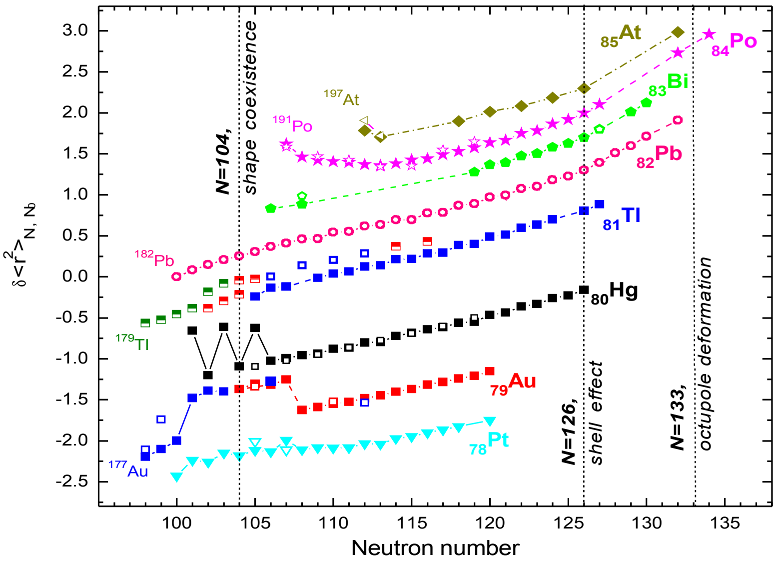

Figure 1: *Charge radii for Pt-At isotopes. For the sake of clarity the data for different elements are shifted relative to each other by a vertical off-set.*

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Beta-decay spectroscopy towards the r-process path

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The study of the structure of neutron-rich Pb isotopes is fundamental to trace the evolution of single-particle levels and the residual proton-neutron interaction beyond the doubly magic nucleus ^{208}Pb. In addition the study of the β decay of neutron-rich nuclei with N$>$126 is of primary importance to understand the stellar nucleosynthesis: in this region the r-process path lies far away from accessible nuclei, therefore nuclear models have to extrapolate extensively to predict nucleosynthesis production rates. Currently two main prescriptions are used: the first includes first-forbidden transitions as a perturbation of the allowed Gamow-Teller decays [1], while the second treats the two contributions on the same level [2]. As a result, the predictions of lifetimes and production rates can vary orders of magnitude.

In this contribution we present results from an experiment focused on the investigation of neutron-rich Pb-Tl-Bi isotopes, carried out within the *Stopped beam Campaign* of the RISING collaboration at GSI. The nuclei of interest were produced by fragmentation of a relativistic U beam impinging on a thick Be target. The residues were identified in the Fragment Separator and finally stopped in the RISING active stopper [3], consisting of 9 DSSSDs which measured position and time of both implanted ions and β electrons. The γ-ray transitions of the daughter nuclei were registered using the RISING Ge array [4], placed in packed geometry around the active stopper.

β-decay half-lives of ^{211,212,213}Tl and ^{218,219}Bi are measured for the first time , as well as the de-excitation of their daughter nuclei ^{211,212,213}Pb and ^{218,219}Po. By comparing the newly measured half-lives to nuclear models built to describe the r-process the importance of first-forbidden transitions is confirmed. These results are well accounted for by the model in ref. [1], at variance from close-lying N$<$126 nuclei which are instead overestimated by this approach [5].

This information is complemented by the study of β-delayed γ spectra giving for the first time an insight on the structure of these nuclei.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Investigation of 0^+ states in mercury isotopes after two-neutron pickup

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In recent years, much effort was invested in systematic studies of low-lying 0^+ excitations in medium- to heavy-mass nuclei, ranging from ^{152}Gd to ^{194}Pt. This region is particularly interesting, as the structure of these nuclei changes from transitional nuclei in the Gd region, over well-deformed nuclei in the Yb region, to γ-soft nuclei in the Pt region [1].

Experiments at the high-resolution Q3D magnetic spectrograph [2,3] in Munich allowed the study of 0^+ states in unprecedented detail using (p,t) transfer reactions, and started with the discovery of an unforeseen high number of low-lying 0^+ excitations in ^{158}Gd [4]. Extending these studies to other nuclei, the enhanced density of low-lying 0^+ states in the Gd region was interpreted as a new signature for the shape-phase transition from spherical to deformed nuclei [5].

By investigating the mercury isotopes, we now probe further towards the end of the proton and neutron shell. Studying their 0^+ excitations is particularly interesting, as they lie in a shape-phase transitional region too: A prolate-oblate phase transition has been identified by investigating several observables from ^{180}Hf to ^{200}Hg [6]. By extending the 0^+ studies to the Hg isotopes, we can test if the low-lying 0^+ density can be applied as a signature of this shape-phase transition as well.

We present the results of our high-resolution study on excited 0^+ states in the mercury isotopes ^{198}Hg, ^{200}Hg, and ^{202}Hg up to 3-MeV excitation energy. In these experiments, we observed significantly fewer 0^+ states than in other experiments of the (p,t) transfer campaign. We discuss the low-energy 0^+ state density as a function of the valence nucleon number N_{val} and test if the 0^+ density can be used as a signature for the prolate-oblate shape-phase transition in the Hf-Hg region.

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Abstract withdrawn

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Lifetime measurement and decay spectroscopy of ^{132}I

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The structure of odd-odd nuclei around doubly magic ^{132}Sn is important to understand and develop the effective proton-neutron interaction near the major shell closure. In the present work, the low lying states of odd-odd ^{132}I, which has three proton particles and three neutron holes with respect to the closed shell configuration of ^{132}Sn, have been characterized from decay spectroscopy. From the systematics of odd proton isotopes in this region, the first excited state of ^{132}I is expected to have contribution from the configurations of $(\pi g_{7/2} \otimes \nu d_{3/2}^{-1})$ and $(\pi d_{5/2} \otimes \nu d_{3/2}^{-1})$. Presence of a high spin isomer in ^{132}I is also reported [1], which appears mainly due to the involvement of unique parity intruder $\nu h_{11/2}$ orbital. The life times of the low lying states of ^{132}I, reported in the literature [2,3], have been found to have wide variations. Recently, the half life measurement has been carried out with BaF$_2$ scintillators from the decay of ^{132}Te radioactive beam [4]. However, BaF$_2$ detectors, though have a very good time resolution, energy selection is difficult as these detectors do not have a very good energy resolution. The latest generation LaBr$_3$(Ce) scintillators, with its good time resolution as well as good energy resolution can overcome this problem. In the present work, the life times of excited states of ^{132}I have been measured from the decay of ^{132}Te, ($T_{1/2}$=3.204 d) using LaBr$_3$(Ce) scintillators. ^{132}Te was produced as fission product of alpha induced fission of ^{235}U. Alpha beam of 40 MeV was obtained from K-130 cyclotron of Variable Energy Cyclotron Centre (VECC), Kolkata. Radiochemical separation of Te from other fission products was carried out and γ-γ-t coincidence data were collected in LIST mode with a setup of three LaBr3(Ce) detectors. The TAC spectrum corresponding to 228-49 keV cascade is shown in Fig.1. The lifetime of the 49 keV level has been extracted by slope method and was found to be 1.002(7) ns. The decay of the high spin isomer (8^-), which cannot be populated from the decay of ^{132}Te, has been precisely measured by separating Iodine from the fission products and following its IT decay with a Low Energy Photon Spectrometer (LEPS) of segmented planar Ge detector. A representative LEPS spectrum is shown in Fig.2, where 96.7 keV is identified as the isomeric decay transition. The details of the decay properties will be presented.

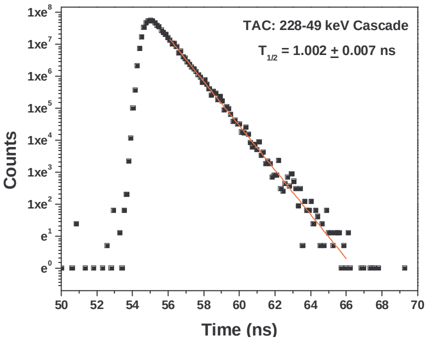

Figure 1: *LaBr$_3$(Ce) TAC spectrum of 228-49 keV*

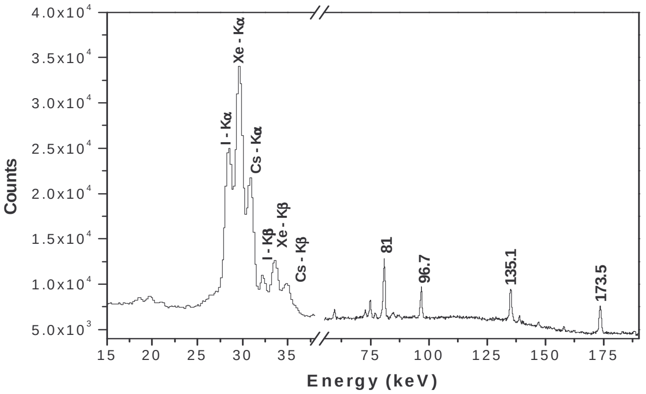

Figure 2: *LEPS spectrum for ^{132}I IT decay*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Spectroscopy of neutron rich nuclei using cold neutron induced fission of actinide targets at the ILL : the EXILL campaign

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To date the most successful method to study the low-lying excited states of neutron-rich nuclei in the mass range A~85-160 has been by placing spontaneous fission sources inside efficient arrays of germanium detectors, such as EUROGAM/EUROBALL or GAMMASPHERE. This method allows the structure of around 250 fission fragments to be studied concurrently. Decay schemes are created by performing γ–γ–γ coincidences, which allow a unique pair of fission fragments to be selected. Unfortunately only two spontaneous fission sources are available for such experiments, ^{252}Cf and ^{248}Cm.

The use of different fission systems would give access to the structure of many new nuclei. An excellent method for cleanly producing very neutron-rich fission fragments, suitable for study using large arrays, is to induce fission reactions in actinide targets using thermal or cold neutrons, from a neutron guide. As neutrons at these energies bring just enough energy into the reaction to produce fission, the fission fragments remain very neutron-rich as there is little prompt-neutron evaporation.

About ten different fissile targets are available for use with this reaction and of particular interest are targets of ^{235}U and ^{241}Pu. These two targets will give access to many nuclei where currently nothing or little is known, especially in the regions north-east of ^{78}Ni and beyond ^{132}Sn. These two regions of the nuclear chart are especially important for testing the interactions used in shell-model calculations far from stability.

In 2012 and 2013, a combination of EXOGAM, GASP and Lohengrin germanium detectors has been installed at the PF1B neutron guide of the ILL (the EXILL campaign). This talk will describe the facility as well as the preliminary results obtained from the various experiments performed during this campaign running for two reactor cycles (100 days).

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Two-proton radioactivity as a tool of nuclear structure

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Two-proton radioactivity is the latest nuclear decay mode discovered. It consists of the emission of a pair of protons from a nuclear ground state. According to the definition by V. Goldanskii who was the first to discuss this new type of radioactivity extensively, one-proton radioactivity is not allowed to be an open decay channel for two-proton radioactivity (2p) candidates.

In pioneering experiments at GANIL and GSI, this new radioactivity was discovered in 2002 and meanwhile ^{45}Fe, ^{48}Ni and ^{54}Zn are established 2p emitters. These results allowed a detailed comparison with the theoretical models available and showed that, at the level of precision of the experimental data and of the predictive power of the models, nice agreement was obtained.

The latest step in the investigation of 2p radioactivity was the use of time-projection chambers to study the decay dynamics via measurements of the individual proton energies and the relative proton-proton emission angle. A first experiment at GANIL and a high-statistics experiment performed at MSU on ^{45}Fe allowed to gain first insides into the decay characteristics by comparison with a three-body model. Meanwhile ^{54}Zn has also been studied with a TPC at GANIL and 2p radioactivity was confirmed for ^{48}Ni at MSU.

The talk will review the experimental results on ground-state two-proton radioactivity and compare these results with theoretical predictions. Future studies and the possible discovery of new 2p emitters will also be discussed.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Search for particle−vibration coupling in ^{65}Cu

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The coupling between particles/holes and vibrations is a key ingredient to explain important phenomena in atomic nuclei, such as transition probabilities, spectroscopic factors, damping of Giant Resonances, etc. [1,2]. The best systems to study particle−phonon coupled states are nuclei around shell closures, where collective vibrations are expected to be quite robust. In recent works, evidences have been found for these kind of states in ^{47,49}Ca, based on the 3^- octupole vibration in ^{48}Ca [3,4].

In this work we investigate ^{65}Cu, which is one proton away from the semi-magic nucleus ^{64}Ni. In particular we focus on the $9/2^+$ state at 2.53 MeV, that is supposed to arise from a weak coupling between a proton in $1\pi p_{3/2}$ and the 3^- octupole vibration at 3.56 MeV in the ^{64}Ni core. Recently the decay branches of this state have been determined [5], but no lifetime measurements are available.

The experiment has been performed at Horia Hulubei National Institute of Physics and Nuclear Engineering (NIPNE) in Bucharest, using the reaction ^{7}Li + ^{64}Ni at 32 MeV. The experimental setup was made by 14 HpGe and 11 Labr$_3$:Cs in 4π configuration. The high energy resolution of HpGe allowed the selection of the reaction products by energy gating, while the excellent timing of the Labr3:Cs scintillators permitted precise lifetime measurements for the $9/2^+$ state in ^{65}Cu. A lifetime of 37(3) ps has been obtained which corresponds to B(E3)=8.82(165) W.u. for the $9/2^+ \rightarrow 3/2^-$ decay to the ground state, which is very similar to the B(E3) strenght of the 3^- phonon in ^{64}Ni [5]. This result has been achieved using fast−timing techniques which are able to provide time information in the range from tens of picoseconds to few nanoseconds [6].

The structure of the $9/2^+$ state in ^{65}Cu has been interpreted within the framework of the particle vibration coupling model, using the weak coupling approximation [1], which reproduces quite well the energy of the state.

In conclusion this work shows that the $9/2^+$ state in ^{65}Cu can be well described as a member of the multiplet arising from the coupling between the single particle state $1\pi p_{3/2}$ and the 3^- octupole vibration in ^{64}Ni, providing a further example of particle−phonon coupling in medium mass systems.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Structure and spectroscopy of ^{24}O drip-line nucleus from (p,p′) scattering

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The studies of structure and spectroscopy of neutron-rich nuclei are important for our understanding of the nuclear structure evolution with isospin towards the drip-line. They have shown, through phenomena like local magic numbers [1,2], that nuclear structure pillars established in the valley of stability are modified. The exotic nuclei have few or no bound excited states which require the use of particule spectroscopy techniques. Low-lying resonances and new magicity represent stringent tests for nuclear theories and their modeling of the nuclear interaction [3-6].

In this context, the excited states of the drip-line N=16 doubly-magic nucleus ^{24}O were intensively investigated. This nucleus has no bound excited state [7]: the spectroscopy was studied via invariant mass method at MSU [8], and recently at RIKEN by Tshoo *et al.* [9]. They have both discussed new excited states and 2^+ deformation was studied in Ref. [9]. In the same period, we used another technique, missing mass method, to investigate the structure and the spectroscopy of ^{24}O via proton elastic and inelastic scattering (p,p′). The experiment was performed at RIKEN in the BigRIPS line, using a high intensity beam of ^{24}O (mean intensity 1700/s) produced at RIBF at 263 MeV/n, and the state-of-the-art charged particle detector MUST2 [10]. In order to check the analysis method, the (p,p′) scattering of ^{22}O at 262.5 MeV/n was measured and the excitation energy spectrum was compared to the one obtained at 46.6 MeV/n at GANIL [11]. The (p,p′) excitation energy spectrum of ^{24}O was deduced but the excited states were not determined due to the very low statistics for the inelastic events. For proton elastic scattering we have enough statistics to obtain and deduce the angular distributions for $^{21-24}$O isotopes.

The talk will present these results, which constitute a unique benchmark to explore proton-nucleus interaction potential features around 260 MeV/n. The comparison of elastic data set to the reaction calculations done with microscopic potentials will be presented. We will discuss the validity of the reaction framework based on the G-matrix density-dependent potentials [12,13] and of the structure inputs.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Quadrupole collectivity in neutron-rich Cd isotopes investigated via Coulomb excitation

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The neutron-rich cadmium nuclei with a proton number of Z=48 are some of the most interesting isotopes in nuclear structure physics due to the proximity to the proton and neutron shell closures at Z=50 and N=82 respectively. The investigation of the excitation energies of the 2_1^+-states shows an irregular behaviour when approaching the neutron shell closure, as the energy of the 2_1^+-state in ^{128}Cd is lower than in ^{126}Cd. So far this finding can not be reproduced by shell-model (SM) calculations although the shell closure is near. Only Beyond-Mean-Field (BMF) calculations with a resultant prolate deformation agree with the low excitation energy of ^{128}Cd. The transition strength B(E2, $0_{gs}^+ \rightarrow 2_1^+$) in the even isotopes $^{122-128}$Cd was measured in Coulomb excitation experiments with the high purity germanium detector array MINIBALL at REX-ISOLDE (CERN). Whereas the values for ^{122,124}Cd coincide with BMF calculations with a resultant prolate deformation ^{126}Cd is better described via SM calculations. Results of the more recent experiment on ^{128}Cd will pursue the picture of the behaviour of the transition strength towards the neutron shell closure. A closer insight in the structure can be obtained by the investigation of the odd isotopes. We started this program with the examination of ^{123}Cd where already discrepancies to the literature were evidenced. In this contribution the latest results of the investigation of the B(E2, $0_{gs}^+ \rightarrow 2_1^+$) values of the even $^{122-128}$Cd nuclei as well as first findings from the recently performed measurement of ^{123}Cd via Coulomb excitation will be presented. This project is supported by BMBF (No. 06 DA 9036I and No. 05 P12 RDCIA), HIC for FAIR, EU through EURONS (No. 506065) and ENSAR (No. 262010) and the MINIBALL and REX-ISOLDE collaborations.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

A shell model description of E3 transition strengths in sd shell nuclei

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A new 0 and 1 ħω interaction called PSDPF [1] has been developed using a fitting procedure to describe the 'intruder' negative parity states in sd shell nuclei which coexist, at relatively low excitation energies, with the 'normal' positive parity states. Note that the normal states are well described in the sd shell model space with an ^{16}O core using USD, USDA or USDB Hamiltonians [2,3]. For the intruders, the model space is extended to the full p-sd-pf with a ^{4}He core and allowing for one nucleon jump between the major shells. PSDPF describes relatively well [1] the energy spectra of negative parity states throughout the sd shell. As an example, the calculated and experimental energies of the first 3^- states in even-even N = Z are compared in Fig.1 (A). It is well known that the electromagnetic transition strengths are a stringent test of the interaction. Using PSDPF, the strength of transitions connecting sd states of opposite parities (ex.: E1 and E3) can now be calculated. As an example, the calculated and experimental E3 strengths of $3^- \rightarrow 0^+$ transitions throughout the shell are shown in Fig.1 (B). The agreement is quite good using effective charges 0.4e and 1.4e for neutrons and protons, respectively. These effective charges are very similar to the ones used to reproduce the E2 strengths throughout the shell [4]. A comparison extended to all known experimental E3 strengths throughout the sd shell with those calculated with PSDPF will be presented and discussed.

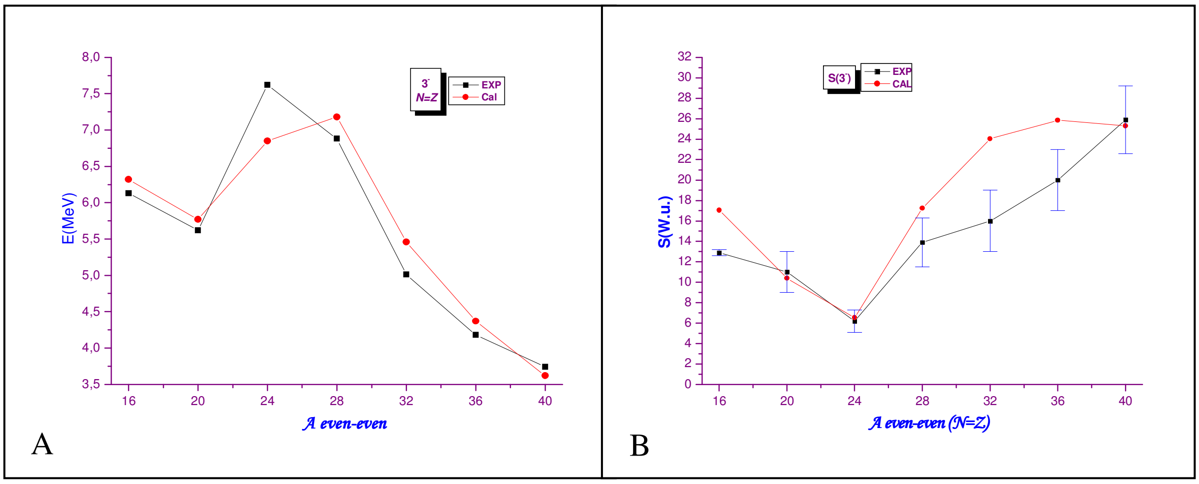

Figure 1: *(A) Energy versus mass for the first 3^- states in even-even sd nuclei with N=Z.*
(B) Transition strength *S(E3) in W.u. versus mass for the* $3^- \rightarrow 0^+$ *transitions in the same sd nuclei.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Extended interacting boson model description up to ^{98}Pd nuclei in the A~100 transitional region

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Detailed studies of even–even nuclei in the A~100 transitional mass region within the framework of the interacting boson model-1 (IBM-1) were performed Ref [1]. This previous work includes collective properties of known $^{100\text{-}104}$Zr, $^{94\text{-}110}$Mo, $^{98\text{-}114}$Ru and $^{102\text{-}120}$Pd and at that time unknown ^{106}Zr, ^{112}Mo, ^{116}Ru and ^{122}Pd isotopes [1]. This work is expanded up to ^{98}Pd nuclei to compare the calculation with new experimental results from measurements obtained at the Institute of Nuclear Physics in Cologne [2]. The energy levels and the electromagnetic transition probabilities B(E2) of $^{98\text{-}100}$Pd nuclei are calculated with refitted parameters from Ref. [1] and show good agreement with the new experimental data as shown in the Figures 1 and 2. The same effective charge e_b=0.097 *eb* [1] is used for calculation of overall B(E2) transitions of $2_1^+ \rightarrow 0_1^+$, $4_1^+ \rightarrow 2_1^+$, $6_1^+ \rightarrow 4_1^+$. It is demonstrated in the Figure 2 that the new results (full symbols) for the B(E2; $2_1^+ \rightarrow 0_1^+$) values of ^{112,114}Pd nuclei [3,4] are more closer to the calculated ones than the previous ones (open symbols). The geometric structure of nuclei is also describe in present work. It is possible to predict the geometry of nuclei by plotting the potential enery surface as a function of β and γ deformation parameters obtained from the IBM-1Hamiltonian in the classical limit. As seen in the right hand side of Figure 1, the geometry of ^{98}Pd is spherical and it is close to the U(5) dynamical symmetry in Casten triangle.

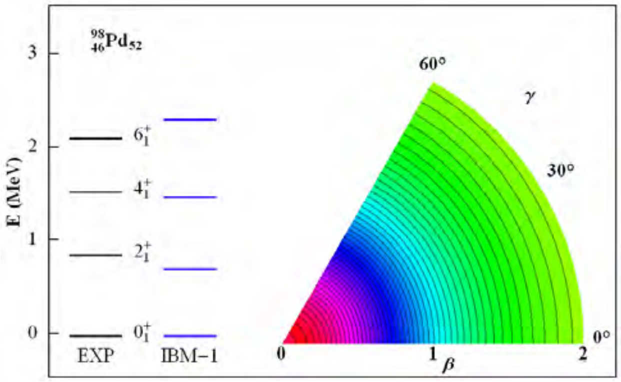

Figure 1: *Experimental and calculated excitation energy energies, and V(β,γ) potential energy surface.*

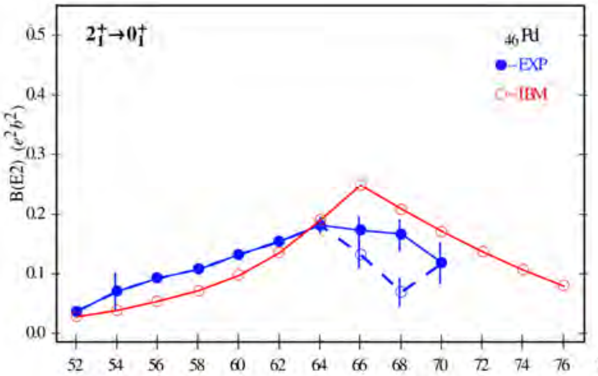

Figure 2: *The experimental (blue) and calculated (red) B(E2) values in the Pd isotopes.*

Acknowledgments: This work is supported by the Scientific and Technological Research Council of Turkey (TUBITAK) - BIDEB 2219-International Post Doctoral Research Fellowship Programme.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Quantum shape phase transitions from sphericity to deformation for Bose-Fermi systems and the effect of the odd particle around the critical point

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Shape phase transitions in odd-nuclei are investigated within the framework of the interacting boson-fermion model with a description based on the concept of intrinsic states. The case of a single j=9/2 odd-particle coupled to an even-even boson core that performs a transition from spherical to deformed gamma-unstable and from spherical to deformed prolate shapes varying a control parameter in the boson Hamiltonian. The effect of the coupling of the odd particle to this core along the shape transition and, in particular, at the critical point is discussed. The critical points for the even-even system with N=5 bosons are located at c = 0,625 for the transition U(5) →O(6) and at c=0.559 for the transition U(5)→SU(3) as seen Figure 1. In the figure the minima in for the different odd-even states are plotted towards the control parameter c. Positive values correspond to prolate deformation, while negative ones mean oblate shapes. Along the transition U(5) to O(6) [1], the states with K = 1/2, 3/2, 5/2 prefer a prolate configuration, while K = 7/2, 9/2 are producing oblate shapes as shown in the Figure 1 (a). In the case of the transition from U(5) to SU(3) [2], the situation is different because the states with K = 7/2, 9/2 prefer oblate deformation when moving towards the critical point and after the critical point they change suddenly to prolate shapes as shown in the Figure 1 (b). This work can be expanded for the transition spherical to oblate and also oblate to prolate by versus control parameter χ for different j.

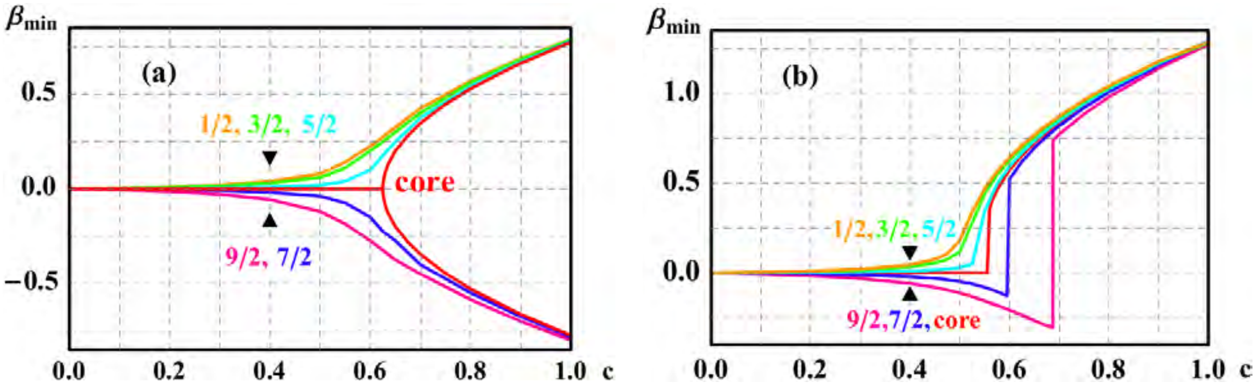

Figure 1: Evolution of the equilibrium deformation parameter corresponding to the different K states in the odd-even system as a function of the control parameter c along the U(5) to O(6) and the U(5) to SU(3) transition. The even-even case is plotted as a reference (red color) for N=5 bosons.

This work is supported by the TUBITAK - BIDEB 2219

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

A microscopic model beyond mean-field: from giant resonances properties to the fit of new effective interactions

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Self-consistent mean-field models are widely used in the description of the atomic nucleus and, as a rule, they achieve successful results for bulk nuclear properties, covering almost the whole chart of nuclides, including the super-heavy and super-deformed regions. Nonetheless, some specific observables, such as the density of states around the Fermi energy, the spectroscopic factors of single-particle states, and the energy and damping properties of collective excitations, require the introduction of correlations beyond mean-field. Including these correlations, some of us have recently developed a completely microscopic consistent models based on the particle-vibration coupling idea (PVC), which employs Skyrme-type interaction and does not contain any adjustable parameters. In this contribution, after a brief overview of the model [1], we will focus on the results obtained for the energy, damping properties and gamma decay of giant resonances [2], which are in good agreement with the experimental findings.

The main limitation of this model is the use of an effective interaction fitted at the mean-field level. Therefore, one should aim at refitting the forces including the desired contributions beyond mean-field in the refitting procedure. If zero-range interactions are used in a beyond mean-field framework, divergences arise and the parameters of the resulting interaction have to properly reabsorb them. This refitting procedure has already been accomplished in infinite nuclear matter [3]. In this contribution, we will discuss the main problems that show up when we want to apply a similar procedure in finite systems.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Beta decay studies of the N=Z and waiting point nucleus ^{72}Kr

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The N=Z nucleus ^{72}Kr is situated in the mass region A≈70-80, where phenomena such as shape coexistence [1,2] and possibly also np pairing effects can show up. From the astrophysical point of view, ^{72}Kr is involved in the rp-process of stellar nucleosynthesis being a waiting point nucleus as ^{73}Rb, next step in the one-proton capture, is unbound and there is a competition between the two-proton capture and beta decay of ^{72}Kr. For this reason, a good knowledge on its beta decay properties such as B(GT) and level lifetimes are of vital importance for astrophysical calculations. From the nuclear structure point of view, ^{72}Kr is an interesting case of an exotic nucleus whose shape (in g.s.) has been predicted oblate [3] and can be inferred by means of beta decay studies as it is exposed next.

Total Absorption Spectroscopy (TAS) studies have previously shown successful results providing information on the shapes of the ground state of nuclei as ^{76}Sr and ^{74}Kr [4,5]. A high resolution beta decay study of ^{72}Kr was done a decade ago [6]. But the conversion coefficients of the de-excitation transitions were not measured and the spin-parity of the low-lying states in the daughter nucleus, ^{72}Br, were not definitely established. Furthermore, the information beyond 1 MeV in the daughter nucleus was rather incomplete. Our aim was to do a complete study of this decay to obtain the B(GT) distribution in the full Q_β window. So we study the different observables with two different setups at ISOLDE, CERN. The low-spin structure of ^{72}Br was determined by the combination of a gamma and conversion-electron detection systems and the study of the beta feeding in the full Q_β window was done by the use of the *"Lucrecia"* TAS spectrometer to obtain the B(GT) distribution.

The experimental B(GT) distribution obtained is compared with two different sets of mean field calculations, on the one hand, performed using the self-consistent HF plus RPA method with different types of Skyrme interactions [7] and, on the other hand, complex excited VAMPIR variational approach calculations [8] in order to extract information on the deformation of the ground state of ^{72}Kr.

Here, we report on the determined conversion coefficients and the spin and parities deduced for the low-lying excited states in the daughter nucleus, ^{72}Br. The comparison of the experimental B(GT) distribution with the best existing calculations sheds light on the deformation of the ground state of ^{72}Kr.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Semi-microscopic description of the proton- and neutron-induced backbending phenomena in some deformed even-even rare earth nuclei

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A semi-microscopic approach to study the double backbending phenomenon in some deformed even-even nuclei from the rare earth region is proposed, based on the band-mixing procedure. In the band-mixing process four rotational bands are involved, namely the ground band, the two $2qp$ bands built on one broken proton or one neutron pair and the band associated with two broken pairs, one of neutron and one of proton type. Each of these bands is defined by a set of particle-core states with a specific single-particle factor function obtained by an angular momentum projection from a quadrupole deformed product state [1].

The protons and neutrons are described by BCS states associated to the restricted space of the $6\nu i_{13/2}$ and the $5\pi h_{11/2}$ orbitals. The intruder particles are coupled through a quadrupole-quadrupole interaction to a phenomenological deformed core described by a quadrupole axially deformed coherent state [2]. The particle-core interaction defines the deformed mean field for the intruder nucleons which also interact among themselves by a pairing force. The projected states are deformed and not orthogonal but can be used to construct an orthogonal basis. The lowest eigenvalues of the model Hamiltonian in this orthogonal basis define the yrast band. Due to the specific construction, the wave function acquires a complex structure which allows a quantitative description of the yrast spectra in the region of the two backbendings as well as a consistent qualitative explanation of the combined contributions of the pair breaking and angular momenta alignment, to the backbending phenomenon and of the possible consequences for the $E2$ transition properties and the state gyromagnetic factors along the yrast band. Four rare earth even-even nuclei, known to be double backbenders, are successfully treated within the proposed approach.

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Nuclear Structure studies with the CRIS beamline at ISOLDE, CERN

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In 2012, two successful experimental campaigns on the new Collinear Resonant Ionization Spectroscopy (CRIS) beam line at ISOLDE, CERN measured the hyperfine structure of the ^{202,203,204,205,206,207,211,218,219,220,221,229,231}Fr isotopes. The CRIS technique combines the high resolution of a collinear laser-atomic beam geometry with the high detection sensitivity of ion detection. While high resolution still requires further development, high detection sensitivity was demonstrated by an efficiency of 1 atom in 60 for ^{202}Fr.

This talk will explain the principle of the CRIS technique and the related equipment and present the hyperfine structure results of the investigated francium isotopes. Two interesting phenomena are present in this region of the nuclear chart. The first is the continued lowering of intruder states, such as the tentative $3\pi s^{-1}{}_{1/2+}$ isomeric intruder state in ^{203}Fr, which is predicted to invert with the ground state at ^{199}Fr. The second is the presence of a region of reflection asymmetry, characterized by almost degenerate doublets of the same spin but different parities in the odd-even nuclei and an alternating spin and parity band sequence (0+ 1- 2+ 3-…).

The final stage of the talk will elaborate on how the newly acquired results will be able to shed light on these interesting phenomena. Furthermore, future plans for studying other interesting regions of the nuclear chart will be discussed.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Emergent collectivity from experimental δV_{pn} values and calculated orbit overlaps

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The structure of atomic nuclei depends on the interactions of its constituents, protons, and neutrons. These interactions play a key role in the development of configuration mixing and in the onset of collectivity and deformation, in changes to the single particle energies and magic numbers, and in the microscopic origins of phase transitional behavior. For example, to experimentally understand average proton-neutron interactions, δV_{pn} [1], double differences of binding energies extracted from high-precision mass measurements have become very useful observables for nuclear structure studies [2]. δV_{pn} is an average interaction strength between the last two protons and the last two neutrons. There are a number of studies of δV_{pn}, both experimental and theoretical (some examples can be seen in Ref. [3]). In this work, for the Z=50-82, N=82-126 shells, considering different deformations, we have calculated spatial overlaps between proton and neutron Nilsson orbits [4]. In this presentation, these calculated overlaps will be compared with the experimental δV_{pn} values and the results will be discussed in terms of the growth of collectivity in nuclei as a function of the numbers of valence nucleons and the orbits they occupy.

This work is supported by the Humboldt Fellowship for RBC, by the Max-Planck Society and the US DOE under Grant No. DE-FG02-91ER-40609.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

An approximate solution of the Dirac equation with trigonometric Pöschl Teller potential for any κ state

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Approximation analytical solutions of Dirac equation with trigonometric Pöschl Teller potential for the arbitrary spin orbit quantum number κ are investigated under the condition of spin symmetry. The approximately analytical bound energy spectrum and their corresponding upper and lower spinor components of Dirac particles are obtained using wave function ansatz method. The valence energy spectrum of particle are presented for the permissible values of the spin symmetry constant C_s. Some useful figures relevant to the Dirac upper and lower spinor wave functions are plotted too.

Properties of Single-particle States in a Fully Self-consistent Particle Vibration Coupling Approach

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The single-particle energies in magic nuclei ^{40}Ca and ^{208}Pb have been studied in a fully self-consistent particle-vibration coupling (PVC) calculations within the framework of Skyrme energy density functional theory. All phonons are produced within fully self-consistent random phase approximation and the same Skyrme interaction is also used in the PVC vertex. In this paper we also discuss the effect on the single-particle energies from the non-central part of the Skyrme interaction, such as the spin-orbit and tensor interaction, it is found that the effect of those interaction is small compared to the effect from the central Skyrme interaction. The effective mass is extracted from the calculated single-particle states.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

α-decay and excited states of ^{111}Xe

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The nucleus ^{111}Xe (Z=54, N=57) lies in the exotic proton-rich region above ^{100}Sn. Having four protons and seven neutrons outside the doubly closed N, Z=50 shell, neutrons and protons in ^{111}Xe will occupy $g_{7/2}$, $d_{5/2}$ and $h_{11/2}$ orbitals. In this region of the nuclear chart, residual neutron-proton correlations are expected to be enhanced since neutrons and protons near the Fermi surface occupy near identical orbitals. This is believed to result in enhanced deformation [1] and octupole correlations [2]. A trend of increasing ground-state deformation has been observed in even-mass xenon isotopes, approaching the proton drip-line [1,2]. Data for the odd-mass xenon isotopes would help elucidate this issue. Furthermore, the ^{109}Xe$\rightarrow$^{105}Te$\rightarrow$^{101}Sn α-decay chain was recently studied by Darby et al. [3] leading to spin assignments for the ground and first excited states of ^{101}Sn. It is important that the neighbouring ^{111}Xe$\rightarrow$^{107}Te$\rightarrow$^{103}Sn decay chain is fully investigated, in order to test assumptions that were made.

Prior to the present work, no excited states had been observed in ^{111}Xe. The α-decay of this nucleus was first studied by Schardt et al. [4] over 30 years ago, and was recently revisited by Cartegni et al. [5]. In the present work, an experiment has been performed at the JYFL facility in Jyväskylä, Finland, in order to study the α decay and excited states of ^{111}Xe, using the ^{58}Ni(^{58}Ni,αn) heavy-ion fusion-evaporation reaction. The JUROGAM II array of Compton-suppressed HPGe detectors was used to detect prompt γ-rays. Recoiling reaction products were separated from the primary beam using RITU, a gas-filled recoil separator, and were subsequently implanted into the DSSDs of GREAT, a highly sensitive detection system at the focal plane. The recoil-decay tagging technique was used in order to perform channel selection. The ^{111}Xe$\rightarrow$^{107}Te$\rightarrow$^{103}Sn decay chain has been used to select ^{111}Xe recoils and to shed light on the ordering of the α-decaying states. New results concerning the excited states and α decay of ^{111}Xe will be presented.

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Isospin mixing at finite temperature in ^{80}Zr

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In the isospin formalism, neutrons and protons are assumed to be different states of the nucleon with values 1/2 and -1/2 of the projection I_z of the isospin operator I.

Isospin symmetry is largely preserved by nuclear interactions and the main violations of isospin symmetry are due to Coulomb interaction. The effect of isospin symmetry violation is that isospin is not a completely good quantum number for the nucleus, but in many cases this effect can be neglected or is small enough to be treated in a perturbative way.

In general, the breaking of isospin symmetry can be observed through the decays which would be forbidden by the selection rules if isospin mixing was not to occur. For example the neutron decay from the IAS or of the E1 decay from self-conjugate nuclei.

The giant dipole resonance (GDR) is an excitation mode where the selection rule of E1 decay can be fully exploited. Fusion-evaporation reactions allow the production of self-conjugate compound nuclei (CN) at high excitation energy which, in many cases, are far from the β-stability valley. The use of a self-conjugate projectile and target ensures that the CN produced in fusion reactions has isospin $I = 0$. Therefore, E1 emission associated with the decay of the GDR is hindered due to the fact that, if the isospin of the initial state is pure, only the less-numerous $I = 1$ final states can be reached in the decay. Conversely, if the initial state is not pure in isospin but contains an admixture of $I = 1$ states, it can decay to the more numerous $I = 0$ final states. The most direct consequence is that the first-step γ yield depends on the degree of isospin mixing of the CN. In addition, at a finite temperature one expects a partial restoration of the isospin symmetry because the degree of mixing in a CN is limited by its finite lifetime for particle decay. The competition between the timescale of the Coulomb-induced mixing and the CN lifetime (which decreases for increasing temperature) drives toward a restoration of isospin symmetry, as already predicted by Wilkinson in 1956.

Isospin mixing in the hot compound nucleus ^{80}Zr was studied by measuring and comparing the gamma-ray emission from the fusion reactions ^{40}Ca+^{40}Ca at E_{beam}= 136 MeV and ^{37}Cl+^{44}Ca at E_{beam}=95 MeV . The yield associated with the Giant Dipole Resonance is found to be different in the two reactions because in self-conjugate nuclei the E1 selection rules forbid the decay between states with isospin I=0.

The experiment was performed at the INFN Laboratori Nazionali di Legnaro using the AGATA-HECTOR array system for the measurement of high and low energy gamma-rays and.

The reaction which has produced the ^{81}Rb hot compound nucleus was used to select the GDR and the statistical model parameters. The degree of mixing at high temperature was deduced from statistical model analysis of the gamma-ray spectrum emitted by the compound nucleus ^{80}Zr.

The results are used to deduce the zero temperature value which can be compared with very recent theoretical predictions. The Coulomb spreading width is found to be independent of temperature and identical to the width of the ground state IAS.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Study of Ground-state configuration of neutron-rich Aluminium isotopes through Coulomb Breakup

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The region of the nuclear chart around neutron magic number, N~20 and proton number (Z), $10 \leq Z \leq 12$ is known as the *island of inversion*. The valance neutron(s) of these nuclei, even in their ground state, are most likely to be found in the upper *pf* orbitals instead of lower *sd* orbitals and thus show deformation from spherical shape. The nuclei like ^{34,35}Al (N=21,22) are lying at the boundary of this *island of inversion*. Little experimental information on ground state configuration of those isotopes are available in literature[1] regarding their intruder *pf-shell* contribution. Coulomb excitation is a direct probe for studying the ground state configuration of loosely bound nuclei [2]. Hence, an experiment was performed using the existing RIB facility at GSI, Dramstadt to study the properties of nuclei in and around the N=20 *island of inversion* through electromagnetic excitation. The exclusive set-up for kinematically complete measurement, the LAND-FRS(R3B) set-up, was used for that. Short-lived radioactive nuclei were produced by the fragmentation of pulsed ^{40}Ar beam (at 531 MeV/u). Secondary beam from FRS, containing various isotopes ^{34,35}Al was allowed to fall on various Pb target for electromagnetic excitation. The incoming beam was identified uniquely by energy loss and ToF measurements before the reaction target along with the known magnetic rigidities of FRS. Neutrons and γ-rays from the de-exciting projectile or projectile like fragments were detected by the LAND and the 4π-Crystal Ball spectrometer, respectively. Reaction fragments were tracked via the Silicon Strip Trackers and GFI detectors placed before and after the magnetic spectrometer (ALADIN), respectively. Finally, mass of the outgoing fragments were identified by reconstructing the magnetic rigidities inside ALADIN and velocity measurements of the reaction fragments. Measurement of four momentum of all decay products and utilization of invariant-mass method leads to the reconstruction of nuclear excitation energy. Comparison of the measured Coulomb breakup differential cross-sections with the theoretically calculated cross-sections provide the ground state configuration and shell inversion in these neutron-rich nuclei. Here, we shall report first time the ground state configuration of ^{34,35}Al, obtained from Coulomb breakup method.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Search for multi-quasiparticle isomers in ^{254}Rf*

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Deformed, axially-symmetric nuclei in the trans-fermium region are known to exhibit high-K isomerism [1], owing to the presence of high-K orbitals near both the proton and neutron Fermi surfaces. The properties of such isomers provide important information on the single-particle structures in the region, as well as on the role played by the pairing and residual nucleon-nucleon interactions.

We have carried out a search for isomeric states in ^{254}Rf using the ^{206}Pb(^{50}Ti,2n) reaction and the Argonne Fragment Mass Analyzer (FMA). A 242.5-MeV beam of ^{50}Ti with an intensity of $\sim$200 pnA was provided by the ATLAS accelerator. The recoiling reaction products were identified at the FMA focal plane by their mass to charge-state ratio and implanted into a DSSD. Both implant and decay events were measured and correlated temporally, and spatially. For the first time, a digital data acquisition system was deployed, which allowed comprehensive pulse-shape analysis of the recoil-decay pile-up events to be performed and identification of implant and decay events separated by decay times as short as hundreds of nanoseconds. Furthermore, this novel approach resulted in a much lower $\sim$50-keV threshold for conversion-electron events, associated with decays of isomeric states within the first 6 μs following implantation, independent from the energy threshold set in the digitizer firmware.

Fission events associated with the known ^{254}Rf ground-state decay were unambiguously identified. In addition, fast ($\sim$2 μs) electron events correlated with an implanted A=254 recoil and followed by a ^{254}Rf ground-state fission events were observed and associated with the decay of a new isomeric state. Evidence was also found for the existence of a second, longer-lived isomer. The data from this experiment will be presented and the results will be discussed in comparison with predictions from multi-quasiparticle blocking calculations that include empirical estimates for the residual configuration-dependent, nucleon-nucleon interactions.

*This work was supported by the U.S. Department of Energy, Office of Nuclear Physics, under Contract No. DE-AC02-06CH11357.

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Correlation Studies of the Low-Energy ^{6}Be Spectrum

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^{6}Be was populated with sufficient efficiency in the excitation energy range up to 16 MeV and full angular range in the c.m.s. of the ^{1}H(^{6}Li,^{6}Be)n charge-exchange reaction. The invariant spectrum shows two peaks corresponding to population of the ground 0^+ and the first excited 2^+ states. These peaks are superimposed on the broad bump with maximum at $E_T \sim 6$ MeV. The main attention of our work is paid to the influence of reaction mechanism on spectra formation. The analysis is based on the theoretical calculations of ^{6}Be structure made in the framework of three-body cluster α+p+p model [1].

Comparison of the model calculations with experimental data in the low-energy part of the spectrum (dominated by the 0^+ state) demonstrates excellent agreement. This observation provides evidence of validity of the applied model and correctness of registration efficiency. Analysis of the energy region $E_T \in (2, 3)$ MeV shows that the formation of the observed spectra strongly depends on the model parameters related to the reaction mechanism.

Complete kinematics measurements with high statistics presents a proper tool to analyze complicated spectra formed by the broad overlapping resonances. We have suggested an adequate approach to analysis of correlation experiments and we assume that obtained results have important implementations for the studies of the few-body decays in general. We expect that further correlation analysis will shed light on the structure of low energy ^{6}Be spectrum.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Giant Dipole Resonance decay of hot rotating ^{88}Mo

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An experiment, using HECTOR and GARFIELD arrays, focusing on study the properties of hot and rotating compound nucleus ^{88}Mo was performed in LNL Legnaro using ^{48}Ti beam at energies of 300, 450 and 600 MeV on ^{40}Ca target. The compound nucleus was produced at temperatures of 3, 3.8 and 4.5 MeV, with angular momentum distribution with $l_{max} > 60\ \hbar$ (i.e. close or exceeding the fission barrier).

High-energy gamma rays, measured in coincidence with evaporation residues and alpha particles, were analyzed with the statistical model. For the analysis the existing GEMINI++ [1] code was enhanced by adding possibility of GDR decay. The correctness of GEMINI++ input parameters which were used to parametrize the level density, the *Yrast* line (and by this deformation of the nucleus in function of angular momentum) was checked by calculating light charged-particle energy spectra and comparing them to the experimental data. Then, during fitting procedure the GDR parameters were obtained, which allowed to investigate an evolution of the GDR width up to high temperatures. Indications of the onset of the GDR width saturation and of the Jacobi shape transition were found. Comparison of experimental results with Lublin Strasbourg Drop model [2] and PDM [3] calculations will be discussed.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Shape coexistence in neutron-rich Sr and Kr isotopes: Prompt spectroscopy after Coulomb excitation at REX-ISOLDE, CERN and after neutron induced fission of ^{235}U at ILL

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A rapid onset of quadrupole deformation is known to occur around the neutron number 60 in the neutron-rich Zr and Sr isotopes. This shape change has made the neutron-rich A = 100 region an active area of experimental and theoretical studies for many decades now. The nuclei here are one of the best examples of the interplay between single-particle and collective modes of excitation leading to spectacular shape change and shape coexistence scenario. In such regions, large variations of the observed spectroscopic properties at a particular proton or neutron number make the theoretical interpretation particularly challenging.

Rapid changes in deformation were first derived from prompt γ-ray spectroscopy and lifetime measurements of fission fragments as early as 1970 [1]. However, in the recent years, modern RIB facilities have brought new insights in this topic. Laser spectroscopy, mass measurement studies of the ground states of the Kr, Sr and Zr isotopes and safe Coulomb excitation measurement of the N=60 ^{96}Kr have been recently performed at ISOLDE-CERN. These new data have defined the low Z boundary of the phenomena pointing a specific proton-neutron interaction stabilizing the nuclei thanks to large deformation [2,3,4,5]. The comparison of the known experimental data with a particular emphasis on the observed spectroscopic properties shows large discrepancies in the transitional region for either mean-field or shell-model like formalism, supporting the need for more spectroscopic information's.

In this contribution, preliminary results on measured spectroscopic quadrupole moments and B(E2) in ^{96,98}Sr isotopes, obtained after safe Coulomb excitation of a post-accelerated RIB delivered by the REX-ISOLDE facility at CERN, will be presented [6,7]. In addition a brief presentation of the recent data collected in the neutron Kr isotopes around N=60 populated by neutron induced fission of ^{235}U at the ILL during the EXOGAM (EXILL) campaign will be shown.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Quantum Nucleodynamics: Bottom-up nuclear structure theory

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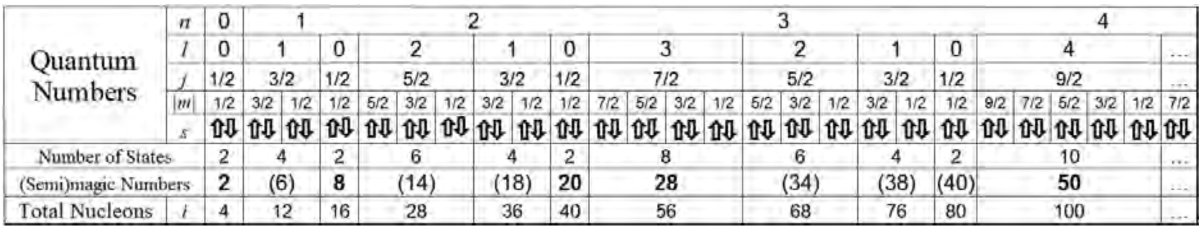
The core ideas underlying a quantitative *theory* (as distinct from a *model*) of nuclear structure, i.e., quantum nucleodynamics (QND) [1], are introduced. The replacement of the "mean-field" approximation of the nuclear force with the empirically-known nuclear potential-well (Paris, Bonn or Argonne) is the essential first step. From there, calculation of short-range (2~3 fm) nucleon-nucleon effects can be achieved on the basis of a lattice representation of nuclear space, as introduced by Wigner in 1937 [2]. The antiferromagnetic fcc lattice with isospin layering leads to quantal states that are *identical* to those in the independent-particle model (IPM) [3] (see Table, below). That is, the unique state of each nucleon, as defined by its quantum numbers (***n, j, l, m, s, i, π***) in the Schrödinger wave-equation, corresponds to a unique, mean position in the lattice, such that a nucleon's quantum numbers can be defined in terms of its lattice coordinates (Eqs. 1-7):

n = (|x| + |y| + |z| - 3) / 2 Eq. 1
l = (|x| + |y| - 2) / 2 Eq. 2
j = (|x| + |y| - 1) / 2 Eq. 3
m = |x| *(-1)^((x-1)/2) / 2 Eq. 4
s = (-1)^((x-1)/2) / 2 Eq. 5
i = (-1)^((z-1)/2) Eq. 6
parity = ***π*** = sign(x*y*z) Eq. 7

Conversely, a nucleon's lattice position can be defined in terms of its quantum numbers (Eqs. 8-10):

x = |2***m***|(-1)^(***m***-1/2) Eq. 8
y = (2***j***+1-|x|)(-1)^(***i***/2+***j***+***m***+1/2) Eq. 9
z = (2***n***+3-|x|-|y|)(-1)^(***i***/2+***n***-***j***+1) Eq. 10

(where x, y and z are the odd-integer Cartesian coordinates that define an fcc lattice) [4].



Quantum Numbers	*n*	0	1			2						3										4					
	l	0	1		0	2			1		0	3				2			1		0	4					...
	j	1/2	3/2		1/2	5/2			3/2		1/2	7/2				5/2			3/2		1/2	9/2					...
	|*m*|	1/2	3/2	1/2	1/2	5/2	3/2	1/2	3/2	1/2	1/2	7/2	5/2	3/2	1/2	5/2	3/2	1/2	3/2	1/2	1/2	9/2	7/2	5/2	3/2	1/2	7/2
	s	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩	⇧⇩
Number of States		2	4		2	6			4		2	8				6			4		2	10					...
(Semi)magic Numbers		**2**	(6)		**8**	(14)			(18)		**20**	**28**				(34)			(38)		(40)	**50**					...
Total Nucleons	*t*	4	12		16	28			36		40	56				68			76		80	100					...

Using the identity between the IPM and the lattice, nuclear binding energies, total angular momenta, parities, radii, magnetic moments, etc., of ground- and excited-states can be calculated, *without* introducing a fictitious "central" potential-well. The current version of QND utilizes 10 variables for the nuclear binding force for 1st-3rd nearest-neighbors of various spin combinations (singlet, s, and triplet, t) and isospin combinations (PP1/2/3, NN1/2/3 and PN1/3). The binding energy coefficients (with all values in the remarkably small range of -1.0~3.0 MeV, see Table below) were obtained by multiple regression analysis of the lattice structures for 273 stable nuclei (16<A<209)(. A complete version of QND will require solving for all ***j, m, s*** and ***i*** permutations of 1st-3rd neighbor nucleon pairs. Higher-order effects are unlikely to be significant.

Factor	*Coeff.*	*Std. Dev.*	*t*	*P-value*	*Factor*	*Coeff.*	*Std. Dev.*	*t*	*P-value*
PP1s	2.715	0.301	9.035	0.000	NN1s	1.804	0.217	8.306	0.000
PP2t	-0.918	0.226	-4.054	0.000	NN2t	-0.332	0.145	-2.284	0.020
PP3s	1.436	0.170	8.449	0.000	NN3s	-0.615	0.116	-5.298	0.000
PN1t	3.025	0.447	6.772	0.000	PN3t	1.208	0.195	6.209	0.000
PN1s	2.258	0.470	4.807	0.000	PN3s	0.338	0.210	1.607	0.109

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Mass dependence of short-range correlations in nuclei and the EMC effect

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An approximate method to quantify the mass dependence of the number of two-nucleon (2N) and three-nucleon (3N) short-range correlations (SRC) in nuclei is suggested. The proposed method relies on the concept of the ”local nuclear character” of the SRC. We quantify the SRC by computing the number of independent-particle model (IPM) nucleon pairs and triples which reveal beyond-mean-field behavior. It is argued that those can be identified by counting the number of nucleon pairs and triples in a zero relative orbital momentum state [1,2]. We find that the relative probability per nucleon for 2N SRC follows a power law as a function of the mass number A. The predictions are connected to measurements which provide access to the mass dependence of SRC. First, the ratio of the inclusive inelastic electron scattering cross sections of nuclei to ^{2}H at large values of the Bjorken variable. Corrections stemming from the center-of-mass motion of the pairs are estimated. Second, the EMC effect, for which we find a linear relationship between its magnitude and the predicted number of SRC-prone pairs. Third, the width of the center of mass momentum distribution in double proton knockout from nuclei. We show that SRC pairs can be tagged by this width. The influence of final-state interactions on the width is studied.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Study of the γ decay of high-lying states in ^{208}Pb via inelastic scattering of ^{17}O ions

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Heavy ions inelastic scattering at approximately 20 MeV/u is a very useful tool to study highly excited states (up to the region of the Giant Quadrupole Resonance), when the measurement of the subsequent gamma decay is also performed with high resolution. Some partial results of the most recent experiments of this type, performed to investigate the electric-dipole (E1) response of nuclei at energies around the particle threshold, are reported. In particular high-lying states in ^{208}Pb nucleus were populated via inelastic scattering of a ^{17}O beam at bombarding energy of 20 MeV/u. Their subsequent gamma decay was measured with the detector system AGATA Demonstrator based on HPGe detectors, coupled to an array of large volume LaBr3:Ce scintillators. Preliminary results in comparison with (γ,γ') data, for states in the 5-8 MeV energy interval, seem to indicate that in that region the states belong to two different groups, one with a isoscalar character and the other with a isovector nature. This is similar to what was observed in other stable nuclei with $(\alpha,\alpha'\gamma)$ experiments. The multipolarity of the observed gamma transitions is determined with remarkable sensitivity by almost continuous angular distribution measurements with AGATA. Data aiming at studying the neutron decay of the Giant Quadrupole Resonance in ^{208}Pb by high resolution measurement of the following gamma decay are also presented in their preliminary form. Similar analysis on ^{90}Zr, ^{124}Sn and ^{140}Ce is currently in progress.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Shell structure, cluster structure and shell-like cluster-structure

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The connection between the cluster and shell models (and further to the quadrupole collective model) was established in the late fifties by Wildermuth, Kanellopoulos, Elliott, Bayman, Bohr et al., in terms of the SU(3) selection rule: the cluster and/or quadrupole collective bands are selected from the shell model basis by their specific SU(3) symmetry. This is an *exact symmetry* symmetry of the spherical harmonic oscillator (HO) applied to a single major shell problem. In this contribution we plan to discuss the extension of these historical studies along different directions.

i) The Wildermuth-connection between the shell and cluster models may hold for more general interactions, too. Necessary and sufficient conditions are presented in terms of *dynamically broken SU(3) symmetry*. ii) The strongly deformed HO also has an *exact SU(3) symmetry* when their frequences (axes) are commensurable (e.g. 2:1:1, 3:1:1) [1]. iii) *Quasidynamical SU(3) symmetry* turns out to be valid even for realistic (Nilsson-type) interactions for (most of) these shapes [2]. iv) In case of the shape isomers of (iii) the strong-coupled cluster and shell model wavefunctions [3] may have considerable overlap, just like for some well-known ground states. (iii) and (iv) together enable us to determine shape isomers, and their clusterization based on symmetry-considerations [4]. v) Multi-major-shell algebraic models have been invented for the description of the shell [5], collective [6] and cluster [7] structure. Their comparision reveals that the common intersection of the three pictures is a $U_v(3) \otimes U_m(3)$ *dynamical symmetry*. vi) For alpha-clustering this dynamical symmetry incorporates qurteting [8]. vii) Different symmetries of the (semimicroscopic) algebraic cluster model correspond to rigid molecule-like and shell-like clusterization. This situation can be discussed in terms of the cold phases and phase-transitions of finite quantum systems [9]. viii) Recent analyses of experimental data both within the shell model [10,11] and within the cluster model [12] show the importance of shell-like cluster structure in nuclei.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Giant dipole resonance in highly excited nuclei

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The evolution of the giant dipole resonance's (GDR's) width and shape at finite temperature and angular momentum is described within the framework of the phonon damping model (PDM)[1], developed by the author and collaborators.

The PDM generates the damping of GDR through the couplings of GDR to particle-hole (ph) configurations, which cause the quantal width, and to particle-particle (pp) and/or hole-hole (hh) configurations, which cause the thermal width. The quantal width decreases slightly as temperature T increases, whereas the thermal with increases with T and saturates at high T. This leads to an overall increase in the GDR's total width at low and moderate T, and its saturation at high T. At very low T (below 1 MeV) the GDR's width remains nearly constant because of thermal pairing.

The PDM description is compared with the established experimental systematic obtained from heavy-ion fusion and inelastic scattering of light particles on heavy target nuclei, as well as with predictions by other independent theoretical approaches. In a recent development, the PDM has been extended to include the effect of angular momentum and its description is compared with the most recent preliminary experimental results of GDR in hot rotating Mo-88 nucleus. The predictions by PDM and the heavy-ion fusion data are also employed to predict the viscosity of hot medium and heavy nuclei. Very recently the PDM strength functions have been averaged over the probability distributions of temperature and angular momentum for the heavy-ion fusion-evaporation reaction, which forms the compound nucleus ^{88}Mo at high temperatures and angular momenta. The results of theoretical predictions are found in excellent agreement with the experimental data.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Shape isomers and their clusterization

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The connection of the quadrupole deformation and clusterization is investigated on a semimicroscopic basis. Special attention is paid to the symmetry-aspects of the problem. In particular: i, super-(SD) and hyperdeformed (HD) states are determined from shape-selfconsistent Nilsson-model calculations, based on their quasidynamical SU(3) symmetries [1-6]; ii, their possible (binary or ternary) clusterizations are obtained from the SU(3) selection rule [1-9]; iii, the energetic preference of the clusterization is determined from different methods, including the double-folding calculations of dinuclear system model [2-4,9] iv, case studies are discussed, when the theoretical predictions (or descriptions) can be compared to experimental observations: SD state of ^{28}Si [5], ^{36}Ar [1,2,4,10], ^{56}Ni [3,4], HD state of ^{36}Ar [1,2,4,10] and ^{40}Ca [6,9].

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Preliminary results of a more accurate measurement of the radiative 4^+ to 2^+ transition in ^{8}Be

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The direct observation of the 4^+ to 2^+ gamma transition in ^{8}Be provided the first electromagnetic signature of its dumbbell like shape [1]. However the large error ~30% in the measured ^{4}He+^{4}He radiative capture cross section did not allow a stringent test of nuclear structure models. The aim of the present measurement was to improve the accuracy by about a factor of 3 so that it could be compared with predictions of the alpha cluster model and *ab initio* calculations which differ by ~20%. This was done by improving the 2-α detection through the use of a 500 μm thick double sided segmented silicon strip detector with 2×16 θ strips and 16 ϕ strips, a 38 BGO detector array for γ-rays, two heavy-met shields surrounding the 1 mg/cm^2 kapton foils (isolating the gas target from the beam line vacuum) to reduce the beam induced 4.44 MeV γ-ray background and making the measurement at 4 beam energies straddling the 4^+ resonance. A 2D spectrum of $E_{\alpha1}+E_{\alpha2}$ vs E_γ, extracted from the event by event data for E_α= 22.5 MeV, is shown in Fig. 1. A band with E_γ ~ 7.5 MeV and $E_{\alpha1}+E_{\alpha2}$ ~13MeV corresponds to the radiative capture events of interest. The preliminary results of the measurement at the 4 beam energies are shown in Table 1. The B(E2) value for the 4^+ to 2^+ extracted from the on-resonance cross section agrees with the cluster model calculation [2] but differs from the earlier *ab initio* calculations [3]. A more precise *ab initio* calculation is awaited [4].

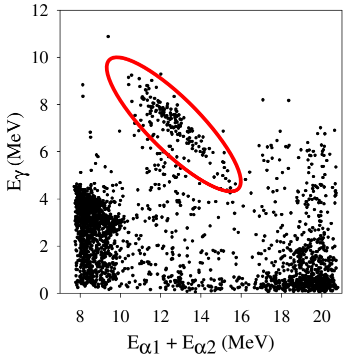

Fig. 1: *2D plot of $E_{\alpha1}$+$E_{\alpha2}$ vs E_γ.*

E_α (MeV)	σ_γ (nb)
19.2	85 ± 10
22.5	134 ± 14
24.7	103 ± 10
28.9	< 32

Table 1: *Radiative capture cross section for 4 beam energies.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Instabilities in Skyrme functionals: identification, detection and applications

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In this talk, we will mainly present linear response theory formalism in the context of symmetric nuclear matter and some of the possible applications.

The linear response theory has been shown, in a recent past, to be the tool of choice for the study of finite size instabilities present in some Skyrme parametrizations (see [1] by instance). More precisely, it has been demonstrated [2,3] that the sum rules satisfied by the spin-isospin response functions can be used to detect - and predict - the appearance of these instabilities. Moreover, since it has been established that there is a correlation between the density at which instabilities occur in infinite matter and the instabilities in finite nuclei, an improved fitting protocol to build stable Skyrme functionals will be presented. This new protocol includes, for the first time, the stability of symmetric nuclear mat- ter up to a given density as a constraint [4]. It has to be noticed that this method is more powerful than the standard constraints based on Landau parameters, since the latter are only valid in the long-wavelength limit and are therefore not able to detect finite-size instabilities.

The starting point of the studies mentioned above was a general Skyrme functional which includes all the terms up to second-oreder (tensor terms). But in a recent past, some extensions of this work, concerning D-wave and three-body terms have been developed and will be discussed.

Finally, for the first time the response functions for the case of asymmetric nuclear matter will be presented [5].

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Ab initio calculations with nonsymmetrized hyperspherical harmonics for realistic NN potential models

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Expansions of nuclear wave functions on a specific basis set is a common tool in few-nucleon ab initio calculations (for a recent review see [1]). Of course, the wave function has to be properly antisymmetrized and this can be quite cumbersome. A frequently used basis are the hyperspherical harmonics (HH). An effective HH symmetrization method had been developed in [2], but the method requires considerable computational resources. Recently a different strategy has been proposed [3,4], where the HH symmetrization is avoided by using nonsymmetrized HH (NSHH). Nonetheless, since the Hamiltonian commutes with the permutation operator, all non degenerate eigenstates of the Hamiltonian have a well defined permutation symmetry. However, additional effort has to be devoted to the determination of the respective symmetry.

Recently we have extended the NSHH method of [2,3] by inclusion of spin and isospin degrees of freedom [5], which allows us to work with modern realistic NN potentials. In addition we have been able to show that the antisymmetric ground state can be identified in a very simple and effective way. Here we discuss the application of our technique to calculate ground-state energies and radii of ^{4}He and ^{6}Li with various NN potential models. In case of ^{4}He we also use the modern realistic AV18 potential.

It might be quite possible that the use of the NSHH is advantageous for HH expansions of nuclear wave functions with more than four nucleons.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Effect of quasi particle number fluctuations on thermodynamical properties of ^{183}W

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We have studied the effect of quasiparticle fluctuations on thermodynamic properties of ^{183}W in the frame work of Modified BCS(MBCS) [1] and Modified Lipkin-Nogami(MLN) [2]. In BCS theory, the symmetry of particle density matrix is broken in temperatures above zero. Modified BCS is a method to restore this broken symmetry. Lipkin-Nogami is another approximate method which restores the particle number symmetry in the frame work of BCS. The Modified Lipkin-Nogami method which also takes the effect of quasiparticle fluctuations into account is its modified version. In this work we study the thermodynamic properties of such as energy, heat capacity, entropy and level density parameter in the frame work of BCS, MBCS and MLN. Our results show that i) gap parameters don't show sharp decrease using the MBCS and MLN formalisms and tend to zero at temperatures higher than 1 MeV, in contradiction with the BCS results ii) heat capacity doesn't show a singular behavior using the MBCS and MLN, although it is singular using BCS formalism iii) better agreement with semi experimental heat capacity [3] is yielded using the modified methods iv) the hump which is observed in the curve of level density parameter versus temperature in the BCS calculations is absent using the MBCS and the MLN.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Effect of statistical fluctuations on thermodynamical properties of ^{98}Mo

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Landau's theory of fluctuations is used to take the effect of statistical fluctuations into account in ^{98}Mo as a fermionic, small, paired system. Mean value of gap parameter is calculated based on the isothermal probability density [1] and is compared with the most probable value of gap parameter. The parameters are used to calculate thermodynamic properties of ^{98}Mo. The results are compared with the conventional BCS results. The smooth behavior of mean value gap parameter makes all the thermodynamical quantities such as energy, entropy and heat capacity nonsingular while the rapid drop of most probable value of gap parameter makes them singular at critical points. Semi experimental [2] data has been compared with the mean value and the most probable value of heat capacity, better agreement with mean value predictions is observed.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Spectroscopy of ^{9}Be and observation of neutron halo structure in the states of positive parity rotational band

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The differential cross-sections of the ^{9}Be + α inelastic scattering at 30 MeV were measured at the tandem of Tsukuba University. All the known states of ^{9}Be up to the excitation energies ~ 12 MeV were observed. Some existing data at higher energies were analyzed as well. The diffraction radii R_{dif} were extracted from the positions of the minima (maxima) of the angular distributions. The *RMS* radii of the levels were obtained by the Modified diffraction model (MDM) [1]. All excited states belonging to the positive parity rotational band 1.68 – 3.05 – 4.70 – 6.76 MeV ($1/2^{+}$ - $5/2^{+}$ - $3/2^{+}$ - $9/2^{+}$) have the radii significantly larger (in average by ~ 1 fm) than those of the members of the K = $3/2^{-}$ ground state band (0.00 – 2.43 – 6.38 MeV). This finding and the comparison with the positive parity rotational states of ^{11}Be whose parameters are quite similar to those of the ^{9}Be band, clearly indicate to their neutron halo structure as it was suggested in [2] on the basis of some limited data. Some large angles cross-sections demonstrate strong oscillation patterns which might be attributed to the ^{5}He transfer reaction and, consequently reflect the existence of the ^{5}He + ^{4}He configuration in the corresponding states including the 1.68 MeV one. The states 2.78 – 5.59 – 7.94 MeV ($1/2^{-}$ - $3/2^{-}$ - $5/2^{-}$) possibly belong to the third rotational band: extrapolation to the state $7/2^{-}$ predicts the excitation energy of the $7/2^{-}$ level to be ~13.8 MeV, the value which is consistent with the existing data. If so, all ^{9}Be states at E* ≤ 15 MeV could be decomposed into three rotational bands with a valence neutron in one of the orbits: $p_{3/2-}$, $s_{1/2+}$ and $p_{1/2-}$

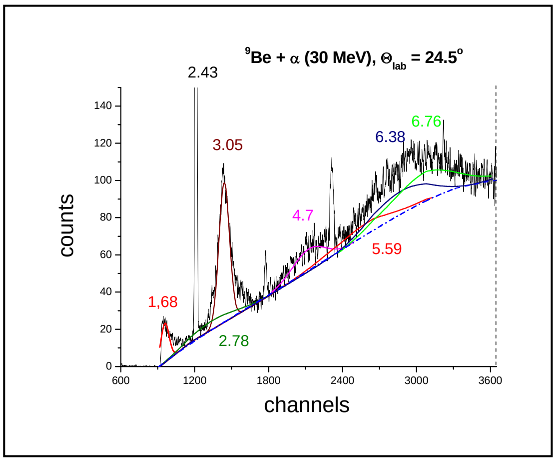

Figure 1: *Sample alpha spectrum*

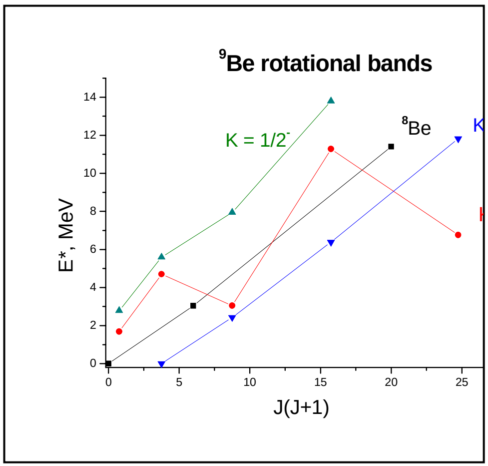

Figure 2: *^{9}Be rotational bands*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Spectroscopy of exotic states of ^{13}C

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^{13}C nucleus is of interest due to co-existence of different structures in its spectrum. Besides the "normal" shell model levels there were observed or predicted some "exotic" states with enhanced radii. In this paper we measured the differential cross-sections of the elastic and inelastic ^{13}C + α scattering at E(α) = 65 MeV with the aim to determine the radii of such states from the experimental data by the Modified diffraction model (MDM) [1]. The chosen energy is quite adequate to the use of MDM. The main attention was devoted to three states: 8.86 MeV ($1/2^-$) one, which is considered to an analog of the 0^+_2, 7.65 MeV (Hoyle) state of ^{12}C; 3.09 Mev ($1/2^+$) state having a neutron halo; 9.90 MeV ($3/2^-$) state, strongly excited in the α-transfer reactions and a possible head of a rotational band. The cross-section of formation of the 8.86 MeV state is shown in Fig.1 in comparison with that for the Hoyle state measured at the same energy. The similar diffraction structure corresponding to the angular momentum transfer L = 0 is observed. The *RMS* radius of the state obtained by MDM is $R_{rms} = 2.69 \pm 0.10$ fm , what is a little smaller than the radius of the Hoyle state ($R_{rms} = 2.89 \pm 0.04$ fm [1]). Both curves in Fig.1 exhibit nuclear rainbow patterns. The observed difference in the positions of the Airy minima also indicates to the smaller radius of the 8.86 MeV state. The radius of the 3.09 MeV state $R_{rms} = 3.01 \pm 0.08$ fm was determined by MDM. Our previous result obtained from the analysis of some published data at lower energies was $R_{rms} = 2.74 \pm 0.06$ fm [2]. An estimate made from the position of the Airy minimum gives $R_{rms} = 3.0$ fm. A neutron halo radius of this state was obtained [3] from the analysis of the ^{12}C(d,p)^{13}C reaction at $E_d = 25$ MeV. It can be used for evaluating the corresponding *RMS* which occurred to be $R_{rms} = 2.68 \pm 0.26$ fm. Thus, all three independent methods gave similar results increasing the reliability both of the halo existence in the 3.09 MeV state and the models used for radii determination. As to the 9.90 MeV state the preliminary analysis shows that the predicted radius enhancement [4] probably does not take place.

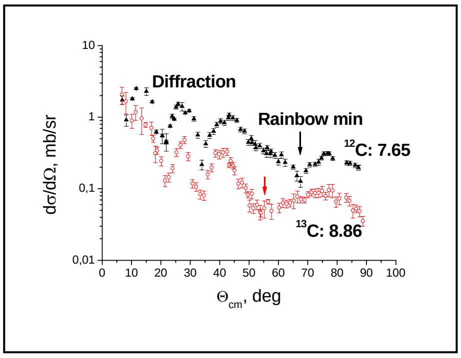

Figure 1: *Differential cross sections at E_α = 65 MeV*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Probing the Character of the Pygmy Dipole Resonance

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In neutron-rich atomic nuclei, a concentration of low-lying $E1$ strength, the electric pygmy dipole resonance (PDR), has been observed below and around the neutron-separation threshold. Its character was studied systematically by using different probes and experimental techniques. Complementary to nuclear resonance fluorescence experiments [1], for a set of nuclei the isoscalar probe of α particles at E_α=136 MeV was used in α-γ coincidence experiments at the Big-Bite Spectrometer [2]. The results permit a separation of the PDR from more isovector parts [2,3]. Most recently, a p-γ coincidence experiment at E_p=80 MeV was performed on ^{140}Ce, previously studied by photons and α particles as a probe [2]. An overview of the particle-γ coincidence experiments and the systematics will be presented.

Supported by the DFG (ZI 510/4-2), EURONS, and the Alliance Program of the Helmholtz Association (HA216/EMMI). V.D. and M.S. are members of the Bonn-Cologne Graduate School of Physics and Astronomy.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

What do the conditions of exact pseudospin symmetry in nuclear relativistic models mean in real nuclei?

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In the last fifteen years, the pseudospin symmetry (PSS) in atomic nuclei has been based by different authors [1-4] on the fact that, in the relativistic framework, the magnitude of the sum of the scalar (S) and the time-like vector (V) components of the nucleon self-energy is small, since the exact PSS is satisfied in the limit $S + V = 0$. However, it has been argued in [5] that this result has only physical meaning for those systems that in the limit $S + V = 0$ are bound. Consequently, since in this limit real nuclei are unbound, there is no reasons to ground the quasi-degenerate pseudospin doublets (PSDs) appearing in real nuclei on the fact that $|S + V|$ is small. Furthermore, in a non relativistic model [6], it was found that standard PSDs, appearing in conditions similar to those of real nuclei, do not correspond to the PSDs found in the limit of exact PSS. Actually, the true PSDs strongly violate the PSS in conditions of real nuclei. In this study we focus on whether these conclusions can also be stated in relativistic models of atomic nuclei.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Structure study of ^{110}Cd via a high-statistics β^+/EC-decay ^{110}In measurement

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The collective Bohr model and the IBM have both used the stable even-even Cd isotopes as classic examples of vibrational nuclei for decades. Experiments with the $(\alpha, 2n)$ reaction, β decay measurements and an $(n, n'\gamma)$ study have identified multi-phonon states in the ^{110}Cd decay scheme indicating vibrational motion. These studies have also suggested intruder configurations based on more deformed 2p-4h proton excitations. There is however evidence of the breakdown of vibration motion in the low-spin states leading to systematic deviations at the three-phonon level that occur across the Cd isotopic chain. Through work done on ^{112}Cd an alternative interpretation has been proposed where the three-phonon 0^+ state is assigned as an intruder excitation.

A study of the ^{110}In β^+/EC decay was performed at the TRIUMF Isotope Separator and Accelerator (ISAC) facility to probe the inherent nature of the ^{110}Cd nucleus. The data were collected in scaled-down gamma singles, gamma-gamma coincidence, and gamma-electron coincidence mode. The data were sorted and a random-background subtracted $\gamma\gamma$-coincidence matrix was created containing a total of 850 million events. We expanded the level scheme of ^{110}Cd significantly by identifying approximately 70 levels under 3.8 MeV, including 12 new ones, and doubled the number of previously observed transitions from these levels to 250. Branching fractions as low as $5.1(3) \times 10^{-4}$ have been extracted.

Internal conversion electron transitions were analyzed using an $e^-\gamma$ coincidence matrix. Sub-shell ratios and multipolarities were calculated the absolute internal conversion coefficients for some mixed transitions were determined. The 396 keV and 708 keV E0 transitions were observed between intruder and spherical phonon states. The E0 transition strength, ρ^2(E0), of $0.115^{+0.077}_{0.066}$ was determined for 708.21 keV line.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Precision mass measurements of short-lived nuclei for nuclear structure studies

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The Precision mass measurements provide some of the most sensitive tools to investigate nuclear structure phenomena. The TITAN Penning trap mass spectrometer facility[1] at ISAC, TRIUMF has a unique set-up, which enables experiments of some of the most important isotopes in current nuclear structure physics. Recent studies that were carried out were focused on neutron-halo nuclei[2,3,4], evolution and disappearance of neutron shells, for example around Ca-52[5] and the Island of Inversion. The mass determinations were possible because of the excellent production capabilities of the ISAC radioactive beam facility, but also because of TITAN's ability to carry out the shortest-lived Penning trap mass measurements[3] (Li-11, t1/2=8.6 ms) and access to highly charged ions to boost the precision[6]. The talk will give an overview of the nuclear structure program at TITAN and the physics impact in particular with respect to modern nuclear theory.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Effective theory for low-energy nuclear energy density functionals

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Our work aims at employing the density functional theory in a form of a convergent expansion, and building an order-by-order correctible theory of low-energy nuclear phenomena. In Ref. [1], we used ideas of the effective theory to construct new classes of nuclear density functionals. For a typical scale of low-energy nuclear phenomena, where the pions mediating the long range part of the nuclear interaction are already too fine a probe to be "seen" by the nucleons, the first thing is to cut-off unresolved high-energy effects that cannot be clearly visible in the low-energy regime. The technology to do so is very well known – one has to employ the so-called regularized contact forces. In practice, this means, for example, replacing delta interactions by peaked functions of a given width, whereupon the width "a" provides the resolution scale. Numerous alternative regularization methods have been invented and employed, such as the cut-off of the high-momentum parts of the delta interaction or a dimensional regularization. Although technically they can be very different, they all do the same job. In our work [1]–[3] we used the Gaussian functions. It is easy to understand that their role is to smear away the details of nuclear densities, thus leaving us with only those parts that vary smoothly. Once this is done, one must describe these smooth variations within a controlled expansion of a gradually increasing precision. This, in turn, is done by regularizing the contact pseudopotentials, that is, the contact forces acted upon by series of differential operators. Up to sixth order, the most general functionals of this kind have been derived [2] and their nuclear-matter properties have been studied [3].

We still do not know how this kind of nuclear functionals will perform in describing the experimental data. Our work only provides a promising hint, by showing a perfect convergence of the series to metadata obtained by employing the standard Gogny functional, see Fig. 1. In future studies, we will attempt the full-blown direct adjustments to data. The biggest challenge is to show that by increasing the resolution scale (decreasing the width of Gaussians) one introduces unphysical high-energy phenomena, and, at same point, in accordance with principles of the effective theory, the theory fails.

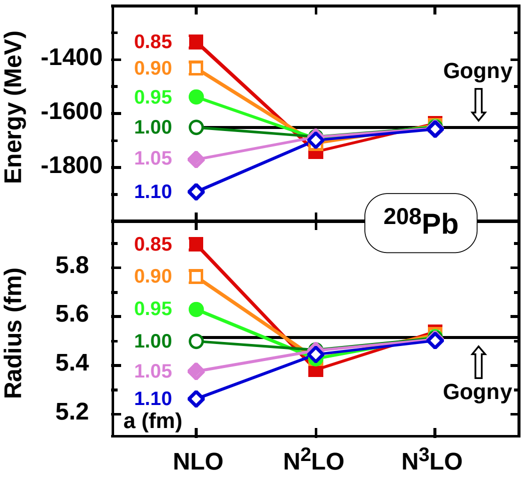

Figure 1: *Convergence of the total energy (upper panel) and proton rms radius (lower panel) in ^{208}Pb.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Spectroscopy and Lifetime Measurement in Neutron-deficient Re and Ir nuclei

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In this work, we present the preliminary results obtained in the experiment: *Search for non-collective transitions in* ^{166}*Os*, performed at the Accelerator Laboratory of the University of Jyväskylä (Finland) in September 2012.

The aim of the experiment has been to measure the lifetime of excited states in neutron-deficient nuclei in the region around ^{166}Os using the recoil distance Doppler shift method (RDDS). In particular we are interested on the investigation of the shape evolution in odd Re and Ir isotopes performed through the determination of the reduced transition probability.

The states have been populated through a fusion-evaporation reaction between a ^{78}Kr beam of 385 MeV energy and a ^{92}Mo target of 1 mg/cm^2 together with a 1 mg/cm^2 thick Ta support. The target was mounted together with a Mg degrader foil of 1 mg/cm^2 thickness in a compact Plunger device, DPUNS, provided by the University of Manchester. Fusion-evaporation products were separated in-flight from fission products using the RITU gas-filled recoil separator and implanted at the focal plane of the GREAT spectrometer. Prompt gamma-rays were detected at the target position by the JUROGAM-2 array consisting of 15 tapered and 24 clover Ge detectors distributed in four rings at different angles with respect to the beam direction. This combined setup together with the Recoil-Decay Tagging (RDT) technique leads an unique opportunity for studying this neutron-deficient region of the nuclear chart.

The results of the work will be discussed in detail at the talk.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Number-projected electric quadrupole moment of even-even proton-rich nuclei in the isovector pairing case

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The effect of the particle-number projection on the electric quadrupole moment (Q_2) of even-even proton-rich nuclei is studied in the isovector neutron-proton pairing case.

As a first step, an expression of the electric quadrupole moment, which takes into account the isovector neutron-proton pairing effect and which conserves the particle-number, is established within the Sharp-BCS (SBCS) method [1-4]. This expression does generalize the one used in the pairing between like-particles case [5].

As a second step, Q_2 is calculated for even-even proton-rich nuclei using the single-particle energies of a Woods-Saxon mean-field. The obtained results are compared with experimental data when available as well as with the results obtained in the pairing between like-particles case. It is shown that the neutron-proton pairing effect, as well as the projection one, is maximal when N=Z.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Deep inelastic reactions and isomers in neutron-rich nuclei across the perimeter of the A = 180-190 deformed region

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The region of deformed nuclei near Z = 72 and N = 104 is prolific in multi-quasiparticle high-K isomers, formed by combining high-Ω orbitals near the proton and neutron Fermi surfaces. Many more are predicted to occur in stable and neutron-rich isotopes but few of these are accessible by conventional fusion-evaporation reactions. As reviewed recently [1], multi-nucleon transfer or "deep-inelastic" reactions with heavy energetic beams offer an alternative, although non-selective, means of production, complementing the broader reach of fragmentation reactions.

We report here on a series of deep-inelastic studies that now extend into the transitional region of neutron-rich W, Ir, Os and Au isotopes . Measurements were made using 6 MeV per nucleon, pulsed and chopped Xe-136 beams provided by the ATLAS facility at Argonne National Laboratory, incident on a range of enriched targets. Gamma-rays were detected with Gammasphere.

As well as some of the technical aspects of discovery, assignment and characterization, newly identified level schemes and isomers in several Os, Ir and Au isotopes [2,3] will be discussed in the context of the tri-axial structures predicted by configuration-constrained potential energy-surface calculations, and also of dynamical effects such as oblate alignment [4] . An emerging issue is that very low-lying states ($K^\pi = 12^+$ and 18^+) associated with the $i_{13/2}$ two-neutron-hole configuration are predicted. These could result in, as yet undiscovered, long-lived β-decaying isomers. Prospects for their identification could include new storage-ring mass techniques [5].

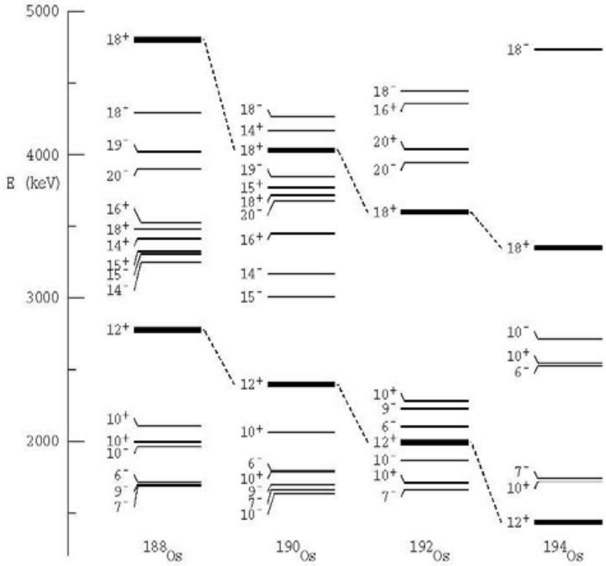

Figure 1: *Predicted multi-quasiparticle intrinsic states from configuration-constrained potential-energy-surface calculations. Note that each state has been independently minimized.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Superheavy Elements studied with TASCA at GSI

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In the quest for superheavy elements, the heaviest element currently claimed in the literature is that with atomic number Z=118 [1]. At GSI Darmstadt, experiments on the synthesis of elements beyond Z=118 have been undertaken in the past two years. The gas-filled "TransActinde Separator and Chemistry Apparatus" TASCA [2], which is optimized for investigations of superheavy elements produced in actinide target-based hot fusion reactions, has proven its excellent performance, e.g., in studies on the synthesis and decay of ^{288,289}Fl (Z=114) [3, 4] and other scientific topics [5].

The two reactions $^{50}\text{Ti} + ^{249}\text{Cf} \rightarrow ^{299}120^{*}$ and $^{50}\text{Ti} + ^{249}\text{Bk} \rightarrow ^{299}119^{*}$ were selected to search for the new elements Z=119 and Z=120 because they are generally predicted to yield the highest cross sections among the feasible reactions leading to these two new elements. In several-months long campaigns, high sensitivity was reached, especially in the search for element 119. In a separate experiment, synthesis and decay of element 117 in the $^{48}\text{Ca} + ^{249}\text{Bk} \rightarrow ^{297}117^{*}$ reaction was studied. The data are currently under analysis.

The results of these three experiments will be presented and their impact on the future perspectives in the search of new elements will be discussed.

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Energy Density Functional description of nuclear quantum liquid and clusters states

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The atomic nucleus is usually described as a collection of nucleons homogeneously distributed in the nuclear volume i.e. a quantum liquid drop. However, nucleons can also form sub-structures by arranging themselves into clusters [1]. However the origin of clusterisation in nuclei is still not completely understood. It is known that deformation of nuclei is a necessary condition for clusters to develop, and that clusterised structures more likely arise in loosely bound systems [1]. Moreover, in neutron-rich isotopes, the valence neutrons act as covalence bounds stabilizing cluster structures and leading to the formation of nuclear molecules [2].

Recently Energy Density Functionals (EDF)-like approaches allowed to predict nuclear clustering [3, 4]. The role of the depth of the mean-field potential in the localization of the single-particle wave functions has been studied: the deeper the mean potential, the more localized the single-particle wave functions. The symmetries involved in relativistic EDF approaches systematically lead to a more pronounced cluster structure as compared to non-relativistic EDF ones (Fig. 1). A parameter measuring the degree of localization of nucleonic single-particle wave functions allows to consider cluster states as a transition phenomenon between a quantum liquid phase and a crystalline one [5].

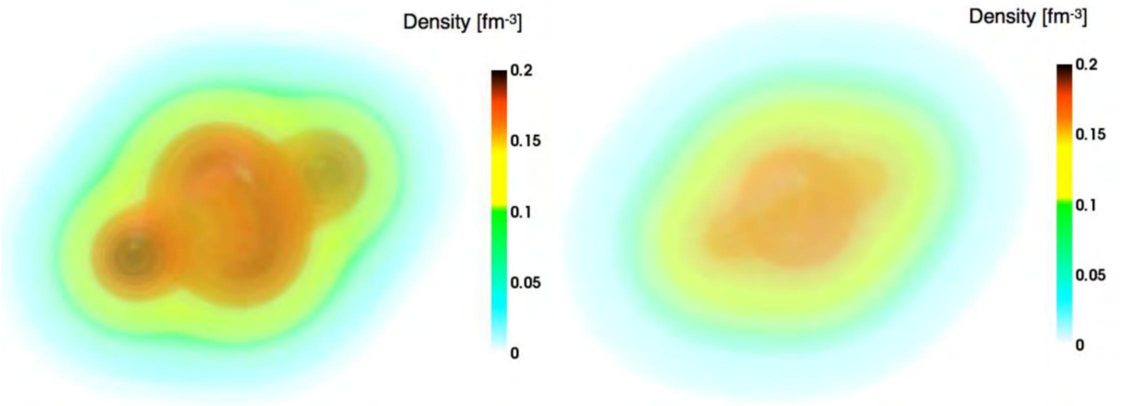

Figure 1: *Total density of ^{20}Ne in its ground state obtained with a relativistic EDF approach (left) and a non-relativistic one (right).*

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Theoretical studies of isovector soft dipole mode

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The population of continuum states in ^{6}Be was studied by using a charge-exchange reaction with ^{6}Li beam at ACCULINNA fragment-separator (JINR, Russia) [1]. A strong population of the negative-parity states by $\Delta L = 1$ transitions far exceeding population of the well-known 0^+ and 2^+ resonances was observed in this work. It was suggested in [1] that this can be interpreted in analogy to the soft dipole mode (SDM) in ^{6}He as a novel phenomenon: isovector soft dipole mode (IVSDM).

In contrast with *resonances*, which properties should be independent on the details of population dynamics, the *excitation modes* are strongly dependent on the initial structure and the reaction mechanism. The classification of the dipole excitations in $A = 6$ nuclei is illustrated in Figure 1. The soft excitation (SDM and IVSDM) are connected with cluster degrees of freedom (e.g. with the very low binding energy of the halo nucleon(s) in ^{6}He), while excitation modes as the giant dipole resonance (GDR) are collective on the level of all nucleons.

We have performed theoretical studies of IVSDM in ^{6}Be in a three-body α+p+p model [2,3]. We emphasize analogies with SDM as well as several important differences between the SDM and the IVSDM, which enable us to consider it as novel phenomenon.

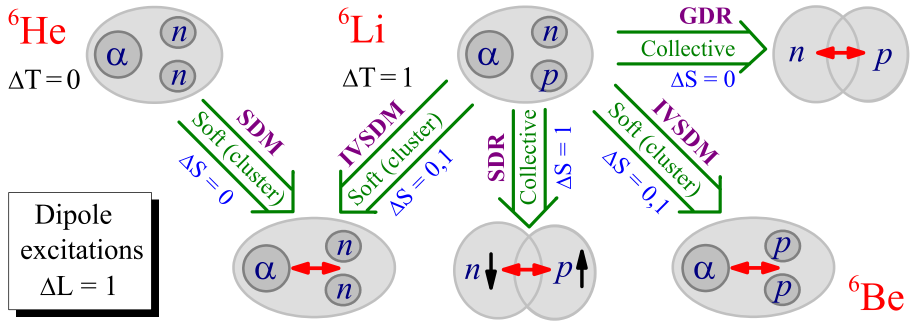

Figure 1: *Classification scheme of dipole excitations in ^{6}He and ^{6}Be prodused in charge-exchange reactions with ^{6}Li [1]. The appearance of the soft dipole mode in the electromagnetic excitation of ^{6}He is shown for comparison. Given is the illustration of difference between the cluster excitations (modes), i.e. the soft dipole mode (SDM) and isovector soft dipole mode (IVSDM), and the collective excitations (resonances), i.e. the giant dipole resonance (GDR) and spin-dipole resonance (SDR).*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Magnetic moment measurement of ^{125}Sb with a new spin-oriented nuclei facility : POLAREX

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Using the OLNO (On-Line Nuclear Orientation) method, POLAREX [1] (POLARization of EXotic nuclei) is a new facility allowing to study the anisotropic decay of spin-oriented nuclei. Based on the combination of on-line implantation of radioactive nuclei with LTNO [2] (Low Temperature Nuclear Orientation) technique and NMR (Nuclear Magnetic Resonance), POLAREX allows to measure nuclear electromagnetic moments and ground-state spins, in the aim to get information about the wave function composition of the nuclear state. Polarized nuclei can also be used to study fundamental interactions involving nuclear β-decay asymmetries.

The low temperature orientation is obtained putting an ensemble of nuclei cooled down to $\sim 10\,mK$ with a ^{3}He-^{4}He dilution refrigerator under an external magnetic field ($\sim 0.5\,T$). The nuclei are in addition implanted into a ferromagnetic foil attached to the cold finger in the cryostat, and oriented through the internal hyperfine field ($10\,T \sim 100\,T$).

The measurements can be made according to two modes: off-line and on-line modes. An on-line measurement means that the nuclei to be oriented are produced by an accelerator and directly implanted inside the dilution refrigerator. Here, the POLAREX infrastructure will be installed to ALTO (Accélérateur Linéaire auprés du Tandem d'Orsay) in order to study neutron-rich nuclei, some of which have not been studied yet.

Will be presented here, this new facility and the preliminary results of its commissioning: the nuclear magnetic moment measurement of ^{125}Sb, and the perspectives for future experiments.

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Stellar electron-capture rates on nuclei based on Skyrme functional

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Weak interaction processes play a pivotal role in the life of a star, especially during the late stages of the evolution of massive stars (see e.g. [1,2]). In particular, during the supernova core-collapse, electron capture on free protons and on exotic nuclei controls the neutronization phase, until the formation of an almost deleptonized central compact object, the neutron star. In this work [3], electron-capture cross sections and rates on nuclei for stellar conditions are calculated for nuclei found during the collapse phase (e.g. iron group nuclei and germanium isotopes), using a self-consistent microscopic approach. The single-nucleon basis and the occupation factors in the target nucleus are calculated in the finite-temperature Skyrme Hartree-Fock model, and the charge-exchange transitions are determined in the finite-temperature random-phase approximation (RPA) approach [4]. The scheme is self-consistent, i.e. both the Hartree-Fock and the RPA equations are based on the same Skyrme functional. Several Skyrme interactions are used in order to provide a theoretical uncertainty on the electron-capture rates for different astrophysical conditions. The results of the calculations show that, comparing electron-capture rates obtained either with different Skyrme sets or with different available models, differences up to one to two orders of magnitude can arise.

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In-Gas Laser Ionization and Spectroscopy experiments

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The in-gas laser ionization and spectroscopy (IGLIS) technique has successfully been applied in the LISOL facility, at the Cyclotron Research Center, Louvain-la-Neuve, to perform high-sensitivity in-gas cell laser spectroscopy studies of the neutron deficient $^{57-59}$Cu [1] and $^{97-102}$Ag [2] isotopes. Production and thermalization of radioactive species in a cell filled with ultra-pure buffer gas is used in combination with resonant laser radiation for selective ionization of the isotopes of interest within the gas cell. Currently, an experimental campaign is being devoted to laser spectroscopy studies of the actinium isotopes $^{212-215}$Ac.

In order to overcome the main limiting factors in the present technique that prevent higher resolution studies as well as extending its applicability to a larger number of isotopes, we propose to perform resonance laser ionization in the gas jet expanding out of the gas cell [3]. In the low-temperature and low-density gas jet the Doppler and pressure broadenings are minimized. This makes the supersonic jet an ideal environment for probing the atomic hyperfine structure in fairly high resolution ($\delta\nu/\nu \sim 10^{-7}$) laser spectroscopy studies prior to the ion capture and transport through different pressure regimes by a Radio Frequency Quadrupole (RFQ) ion guide system.

Proper implementation of in-gas jet laser spectroscopy for the study of rare isotopes requires though optimum temporal [4] and geometrical overlaps of the lasers with the atomic beam, and in addition narrow-band laser radiation: For optimum temporal overlap high repetition pulse rate lasers ($\sim$15 kHz) will be employed. A combination of a low-divergence atomic jet, created by specially shaped nozzles, and a RFQ ion guide system is proposed to maximize the spatial overlap. Finally, amplification of a single mode diode laser radiation in a pulsed dye amplifier will provide narrow laser linewidths. Optimization of in-gas jet laser spectroscopy will be carried out in off-line studies at the new HELIOS laboratory currently being commissioned at KU Leuven. Once in full operation the apparatus will be moved to S^3 (GANIL) to perform high-sensitivity ($\leq$1 ion/s) and high-resolution ($\sim$200 MHz) laser spectroscopy studies on radioactive species.

Results in offline conditions on the performance of the new RFQ ion guides as well as on the use of the apparatus to perform high resolution laser spectroscopy studies in a free jet [5] will be presented.

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Spectroscopy of Element 115 Decay Chains

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B. Lommel[2], A. Mistry[6], C. Mokry[4], H. Nitsche[5], J.P. Omtvedt[9], P. Papadakis[6], I. Ragnarsson[1],
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During the past decade, a number of correlated α-decay chains, which all terminate by spontaneous fission, have been observed in several independent experiments using ^{48}Ca-induced fusion-evaporation reactions on actinide targets [1]. These are interpreted to originate from the production of neutron-rich isotopes with proton numbers $Z = 113\text{-}118$. However, neither their mass, A, nor their atomic number, Z, have been measured directly.

In November 2012, a three-week experiment was conducted at the GSI Helmholtzzentrum für Schwerionenforschung GmbH in Darmstadt, Germany, using high-resolution α, electron, X-ray and γ-ray coincidence spectroscopy to observe α-X-ray events to identify uniquely atomic numbers of isotopes in $Z = 115$ decay chains. The reaction ^{48}Ca+^{243}Am was used, with fusion-evaporation products being focused into the TASISpec set-up [2-4], which was coupled to the gas-filled separator TASCA [5,6].

A beam integral of roughly $7 \cdot 10^{18}$ ^{48}Ca particles led to the observation of about 25 correlated α decay chains with characteristics similar to those previously published [7,8]. Results from the ongoing data analysis will be presented.

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Review of critical point symmetries and shape phase transitions

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We review the concepts of critical point symmetries[1, 2] and the onset of shape phase transitions [3] in even and odd systems within the frameworks of the Interacting Boson Model(IBM) and the Interacting Boson Fermion Model(IBFM) respectively. Comparisons are made with geometric models based on the solution of the Bohr hamiltonian[4, 5]. While the focus is mainly theoretical, we will briefly discuss experimental signatures of shape phase transitions and compare them with models. Along with the E(5) and X(5) symmetries, we also treat the case of an odd particle (sitting in one or more single particle orbitals) coupled to an even-even boson core that undergoes a transition from the spherical limit to the deformed limit [6,7] and other cases [8,9]. Energy spectrum and electromagnetic transitions are analyzed in detail. The additional particle characterizes the properties at the critical points in finite quantum systems. The formalism of the intrinsic or coherent states is used to describe ground- and excited beta- and gamma-bands. The potential energy surfaces obtained from model hamiltonians are put in correspondence with the cases proposed within the geometric collective model based on the Bohr hamiltonian.

If time permits we will also discuss the emergence of triaxiality in even-even nuclei due to the cubic quadrupole operator, $(Q \times Q \times Q)^{(0)}$ and the phase transitions associated with this phase.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Neutron halo in ^{14}B studied via reaction cross sections

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Reaction cross sections (σ_{R}) for the neutron-rich nucleus ^{14}B on Be, C, Al and CH_2 targets have been measured at several energies in the energy range of 45−120 MeV/nucleon where the σ_{R} is sensitive to dilute densities at the nuclear surface. The one-neutron separation energy for ^{14}B is so small as 0.97 MeV and relatively narrow widths of the momentum distribution of ^{13}B fragments produced from ^{14}B beams were observed in previous studies[1]. While the importance of the contribution from the 2s configuration was argued in those studies, the detailed determination of the nucleon density distribution at the nuclear surface of this nucleus will be also valuable for the structure study.

^{14}B secondary beams were produced from a 160A MeV ^{18}O and a 160A MeV ^{15}N primary beams provided by the heavy-ion synchrotron HIMAC and separated through the secondary beam line at National Institute of Radiological Sciences, Japan.

The results compared with the systematics of stable nuclei from the empirical formula by Kox et al. [2] are shown in Fig. 1 (a). The present σ_{R} data shows 20−30 % enhancement relative to the systematics. In order to reproduce the data with Glauber calculation, it was found that a tail in the density distribution such as shown in Fig. 1 (b) is necessary. The nucleon density distribution of ^{14}B deduced from the experimental σ_{R} data through the modified Glauber calculation and the nuclear structure of ^{14}B will be discussed.

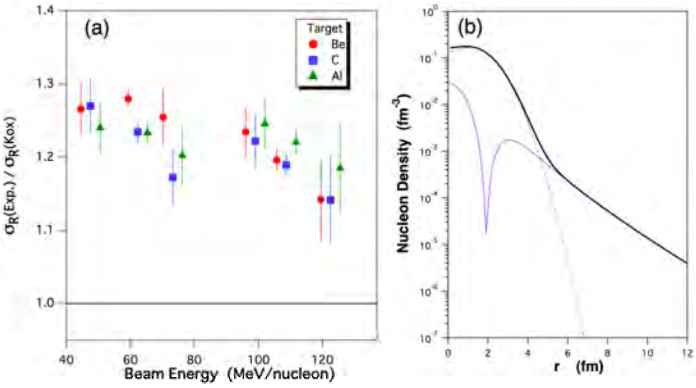

Figure 1: *(a) Present σ_{R} data compared with the systematics, (b) a nucleon density distribution that can reproduce the data well.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Present status of study on alpha-particle condensation in nuclei

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Special attention has recently been paid to the quantum condensates consisting of finite number of α particles in nuclei[1], which can be regarded as an analogue to the α-particle condensates in infinite nuclear matter. It is now well established that the famous Hoyle state, the second 0^+ state in ^{12}C, strongly has the α-particle condensate character, as a product state of 3α particles which occupy an identical S-orbit [2-4], with a dilute gas-like structure of weakly interacting α particles. The family of the α condensate is also predicted both theoretically and experimentally. For instance, the second 2^+ state in ^{12}C was observed at a few MeV above the Hoyle state in several independent experiments [5-8]. The resonance parameters predicted by the α condensate model well agree with the observed values [9]. Further study of investigating this novel states in heavier nuclei is crucially important. In this contribution, we discuss the present status and recent progress of the work on the α condensation. As the recent progress, we discuss the 4α-particle condensate state in ^{16}O. The study is done with the semi-microscopic approach, 4α Orthogonality Condition Model (OCM), where a huge model space is taken so as to cover the α+^{12}C [10,11] and the dilute 4α configurations as well as the shell-model-like one of the ground state. We can tentatively make a one-to-one correspondence of the calculated 0^+ states up to the 0_6^+ state with the lowest six 0^+ states of the experimental spectrum [12]. The 0_6^+ state found at 2 MeV above the 4α threshold has large α condensate fraction and strong concentration on zero momentum, which are clear indications of the 4α condensate. The 0_6^+ state might correspond to the 15.1 MeV state in experiment. Non-zero spin excitations of the 4α condensate are also shown to exist, which have the α+$^{12}\mathrm{C}(0_2^+)$ rotation character. These can be considered as the Hoyle-analog states, where he Hoyle state accompanies the remaining α particle like a satelite. The structural change from the $\alpha+{}^{12}\mathrm{C}(0_2^+)$ rotation to the 0_6^+ state is also discussed. Since all these results are obtained within the bound state approximation, we further extend this study to investigating resonances with proper boundary conditions. The Complex Scaling Method (CSM) is a powerful method to treat such many-body resonances in nuclear systems. We report the results of applying this method. This will be an essential study to put a firm theoretical footing on existence of the 4α condensate state.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Recent progress in the description of pairing in nuclei (at zero and finite temperature)

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Pairing correlations in nuclear systems play a crucial role in several aspects: binding energies and odd-even effects, superfluid phenomena and pair transfer mechanisms, just to quote few of them. On the theoretical side, the standard description of these features is done by using BCS or HFB models that allow to describe in a simple way pairing effects. However, due to the explicit breaking of the particle number, these theories present some limitations which can be cured by using particle number projection techniques. In the quest of accurate description of superfluid systems, we have systematically tested mean-field based method to predict ground states, excited states as well as thermodynamics properties in the schematic pairing model (Richardson model). In all cases, severe limitations have been identified and theories beyond BCS-HFB have been proposed. These theories will be illustrated to show the improvement of the spectroscopy [1], the pair transfer process [2] as well as the thermal transition from normal to superfluid finite systems [3]. Finally, the contribution of pairing correlations to the specific heat of the isotopes ^{161},^{162}Dy will be analyzed within a canonical framework and some recent results will be shown and discussed.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Microscopic Optical Potential with Two and Three Body Forces for nucleon-Nucleus Scattering

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We report the calculations of the microscopic nucleon – nucleus optical potential based on the Brueckner-Hartree-Fock (BHF) approach. For the calculations of the required g – matrices, we use several inter nucleon (N - N) potentials like Urbana v14 (UV14), Argonne v14 (AV14), Argonne v18 (AV18), Reid93 and NijmII along with and without two types of three body forces (TBF): Urbana IX model (UVIX) and the phenomenological density dependent three nucleon interaction model TNI of Lagaris, Friedman and Pandharipande. The inclusion of TBF helps to reproduce rather well the saturation properties for symmetric nuclear matter as expected. The nucleon - nucleus optical potentials obtained by folding the calculated reaction or g- matrices (with and without three-body forces) over the target nucleon density distributions obtained from the relativistic mean field theory, are then successfully used for the calculation of the experimental observables (e.g. differential cross section ($d\sigma / d\theta$), polarization (A_y), spin rotation function (Q)) of the nucleon – nucleus scattering. It is found that (1) the inclusion of TBF reduces the strength of the central part of the optical potential in the nuclear interior and affects the calculated spin-orbit potential only marginally, (2) the calculated volume integral of the real spin orbit as well as the peak value of spin orbit potential systematically decreases with the addition of neutrons, (3) the first maximum in analyzing power decreases as a result of weakening of the spin-orbit potential and (4) the inclusion of three-body forces (Urbana IX (UVIX) and TNI) in BHF does not lead to any substantial change in the calculated $d\sigma / d\theta$, A_y, and Q. In general the agreement between the calculated results and the corresponding experiment is rather impressive. These observations hold for all the cases studied and therefore can be considered to be general. For illustration, some results of the representative cases are presented and discussed.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Propagation of uncertainties in the Skyrme energy-density-functional model

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In the present work [1] we used the Skyrme EDFs [2] within the Hartree-Fock-Bogoliubov (HFB) method to calculate the uncertainties of observables in all even-even semi-magic nuclei with N = 20, 28, 50, 82, and 126 and Z = 20, 28, 50, and 82 extending between the two-proton and two-neutron driplines. To determine the propagation of uncertainties from the model parameters to some observable, one needs information about the standard deviations and correlations between the model parameters. In this work, we have chosen to use the UNEDF0 parameterization of the Skyrme EDF, for which such information has been provided in Ref. [3]. The calculations were carried out by using the computer code HOSPHE [4, 5], which solves the HFB equations in a spherical harmonic-oscillator basis. The results show that typically the magnitude of theoretical uncertainty increases towards neutron rich regime. This is linked to large uncertainties of the isovector parameters in the used EDF.

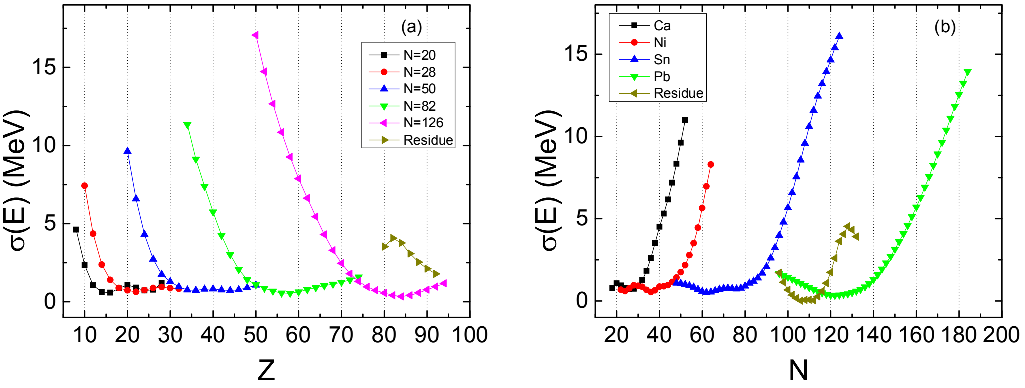

Figure 1: *Standard errors of binding energies of semi-magic nuclei calculated for (a) isotonic chains with magic neutron numbers and (b) isotopic chains with magic proton numbers. For the Pb and N=126 nuclei, moduli of fit residuals with respect to experimental data* [6] *are also shown.*

In Fig. 1, we present the calculated standard errors of binding energies of semi-magic nuclei. The left panel shows the isotonic chains with magic neutron numbers of $N = 20$, 28, 50, 82, and 126 and the right panel shows the Ca, Ni, Sn, and Pb isotopic chains. Within the experimentally known regions of nuclei, standard error usually stays rather constant and is typically of the order of 1 MeV. Moving to the neutron rich regime, calculated standard error increases rather steadily. The values reached there can be of the order of 10 MeV. For the Pb and N = 126 nuclei we also show the moduli of fit residuals with respect to experimental data [6].

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

The evolving structure of the Cd isotopes

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The even-even Cd isotopes have long been cited as one of the prime examples of vibrational behaviour (see, e.g., Ref.[1]). Indeed, the low-lying level schemes of the mid-shell Cd isotopes display excitation energy spectra that are nearly idyllic for an vibrational nucleus, but also include additional states that were identified with deformed intruder-band structures. Initial measurements [2,3] of absolute $B(E2)$ values for transitions between the multiphonon states appeared to reinforce the structural interpretation of mixing between a family of normal vibrational states and coexisting deformed states [4].

Motivated by the question of how high in excitation the collective vibrational states survive, a series of measurements with the powerful $(n, n'\gamma)$ reaction on ^{110,112,114,116}Cd were made [2,3,5,6,7]. Each study found deviations between detailed Interacting Boson Model-2 (IBM-2) model predictions and the experimental data that, when viewed separately, were not necessarily considered serious. However, when the ensemble of data was considered, a compelling case for serious departures from vibrational behaviour could be made [8]. This motivated a program of highly-detailed studies by our group using the 8π spectrometer at the TRIUMF-ISAC radioactive ion beam facility, as well as a program of study by the UNIRIB collaboration of the neutron-rich Cd isotopes at HRIBF [9,10]. The studies with the 8π spectrometer have included to date the β decay of ^{110}In and ^{112}In/Ag to populate states in ^{110,112}Cd, with a focus on very weak γ-ray branches between highly-excited states. Further, we have also pursued studies of the nuclear structures of the even-even Cd isotopes using transfer reactions, such as the $(\vec{d}, p)$, (p, α), (d,^{3}He), and (p, t) reactions. These new data have resulted in a paradigm shift in our understanding of the structure of the Cd isotopes, in particular that the even-even Cd isotopes may represent deformed γ-soft rotors rather than spherical vibrators [11,12], a suggestion backed by recent theoretical calculations [13].

This presentation will focus on the long journey of the evolution in our understanding of the structure of the Cd isotopes starting with the ground-breaking systematic studies of the Jyvaskyla group (see, e.g., Ref. [14]), the necessity of multi-spectroscopic probes being brought to bear, and the usefulness of taking a new look at our "well-known" paradigms and the surprises they may have in store.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Isomer and beta decay spectroscopy in the ^{132}Sn region with EURICA

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The first EURICA campaign with high intensity Uranium beams took place at RIKEN in November/December 2012. Within this campaign experiment NP1112-RIBF85 was performed dedicated to the study of the isomeric and beta decays of neutron-rich Cd, In, Sn and Sb isotopes beyond the N=82 neutron shell closure. The exotic nuclei (compare Fig. 1) produced in the projectile fission of a Uranium beam with energy around 345 MeV/u were implanted and their beta decays detected in the WASABI Si array consisting of a stack of eight DSSSD. The γ-rays emitted from isomeric states or after beta decay were measured with the EURICA array consisting of 12 Cluster detectors of the former EUROBALL array (in total 84 Ge crystals).

The combination of the unprecedented high intensity of the primary U beam (on average 8-10 pnA) and the high efficiency of the setup for both the detection of γ-rays and particles allowed to perform detailed decay spectroscopy in a region of the chart of nuclides which has not been accessible for this type of studies before. As one example we mention the observation of a new isomeric state in ^{136}Sn. In this contribution we will briefly introduce the EURICA project, then present first experimental results from NP1112-RIBF85 and finally discuss why we believe that they present real challenges to modern shell model theory in this neutron-rich region.

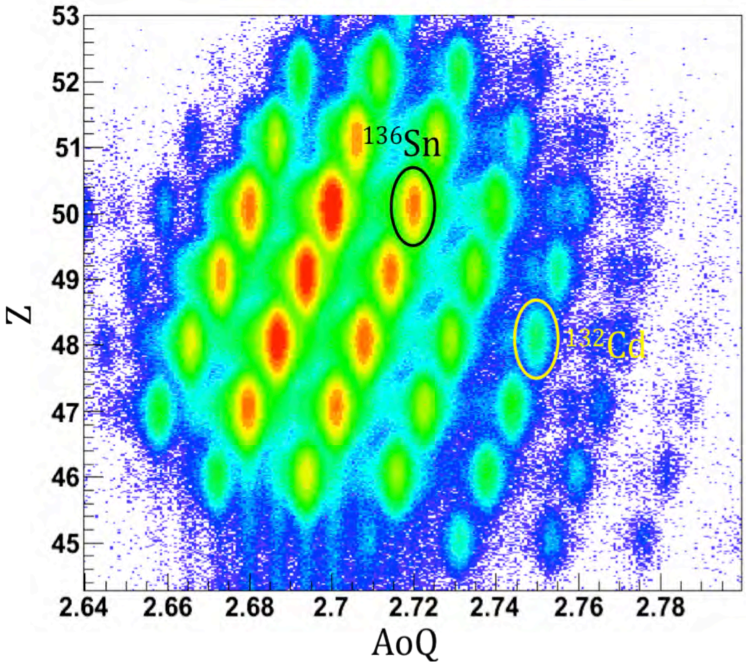

Figure 1: *Preliminary fragment identification plot from BigRIPS for experiment NP1112-RIBF85.*

Spherical and deformed structure in $N = 50$ medium mass nuclei

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The spherical as well as deformed structures in $N = 50$ Ge, Se and Kr nuclei have been investigated using angular momentum projected Hartree-Fock (PHF) model [1, 2]. We show that the deformed bands can be formed by taking into account well-deformed HF solutions obtained by using a quadrupole constraint, other than the ‘almost’ spherical solutions which give ground band systematic. The HF energy surfaces for these nuclei are shown in Fig. 1. The large deformation causes the migration of deformed levels from the shell above the $N = 50$. A deformed well-mixed $\Omega = 1/2^+$ neutron orbit comes down in energy to break the $N = 50$ spherical shell closure. Our study gives insight into possible deformed structures at spherical shell closure. As an example, the band spectra of ^{82}Ge is shown in Fig. 2 and compared with the recently observed deformed bands [3]. The first deformed band (denoted by D1 in Fig. 2) built on the constrained HF configuration has rotational structure. We excite two neutrons from the orbits $\pm 7/2^+$ below the neutron Fermi surface to the well-mixed $\pm 1/2^+$ orbit above the neutron Fermi surface in order to get the second deformed rotational band, D2 of Fig. 2. A fairly good agreement between calculated and available experimental results is achieved for this case. We also obtained few more bands based on unconstrained (represented by solid lines in Fig. 2) as well as constrained (represented by dotted lines in Fig. 2) HF solutions.

SKG acknowledges the financial support of the Council of Scientific & Industrial Research (CSIR), Govt. of India (Project No 03(1216)/12/EMR-II) during this work. CRP acknowledges the support of the Department of Science and Technology, Govt. of India (DST Project SR/S2/HEP- 37/2008) during

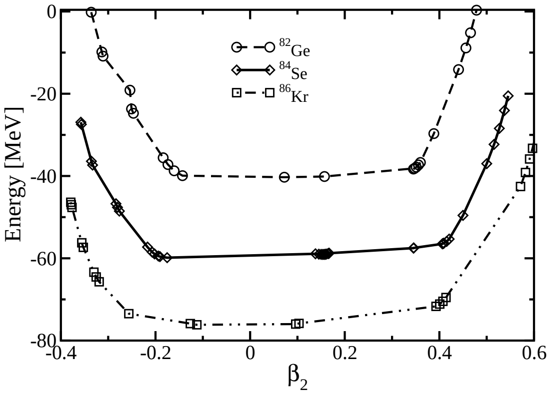

Figure 1: *Hartree-Fock energy as function of quadrupole deformation parameter.*

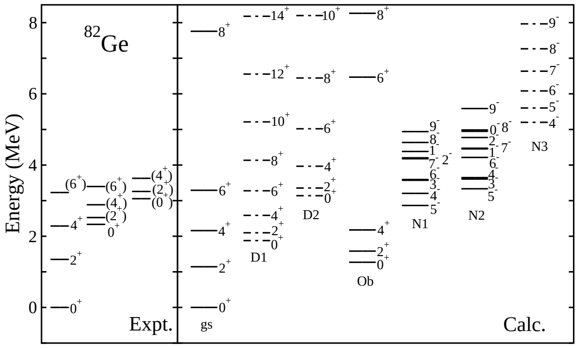

Figure 2: *Comparison of experimental spectra (Expt.) [3,4] and PHF model results (Calc.) for ^{82}Ge.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Beta-delayed fission of neutron-deficient Fr and At isotopes *

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Beta-delayed fission (βdf) happens when a precursor nucleus first undergoes beta-decay to a high-lying excited state above or around the fission barrier in the daughter nucleus that subsequently fissions. Although βdf is a rare event, its study allows us to probe the nuclear fission process of excited nuclei with low excitation energies and known ranges of spins and parities as shown from our previous work on the βdf of 180Tl where an unexpected asymmetric mass distribution in the fission fragment distribution was observed [1].

Since 2009, a number of experiments on βdf in the neutron-deficient lead region have been carried out at CERN-ISOLDE. At ISOLDE, protons are impinging on a UC_x target, creating a wide range of atomic nuclei. Via selective ionization mechanisms (eg. Laser ionization) and subsequent mass separation, pure isotopic beams can be created. The latter are then implanted on ultrathin carbon foils, mounted on a rotatable holder. Silicon detectors placed on both sides of the carbon foil are used to detect emitted fission fragments. In this contribution we report on the latest results of this experimental campaign whereby the βdf of ^{200,202}Fr (May 2011) and of ^{194,196}At (May 2012) was studied.

For all mentioned nuclei, βdf has been firmly identified and for ^{194,196}At and ^{202}Fr, enough statistics were collected to construct energy and mass spectra of the fission products. Although the data analysis is still ongoing, compared to the ^{180}Hg case a different fission fragment mass distribution is observed. This indicates that these nuclei represent a transition region between asymmetric and symmetric fission as observed in the heavier Rn and Ra isotopes studied via Coulomb excitation induced fission [2]. The results will be discussed in a more global framework of fission studies in this mass region.

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*This work was performed by RILIS-ISOLDE(CERN) – UWS,Paisley (UK) - IKS,KU Leuven (Belgium)-Comenius University, Bratislava (Slovakia)-OLL, University of Liverpool (UK)-JAEA, Tokai (Japan) –SCK•CEN, Mol (Belgium) collaboration.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Statistical gamma-ray emission of gold and its astrophysical implications

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The density and width of nuclear excited states increase with excitation energy towards the particle separation energies creating a quasicontinuum of levels in heavier nuclei. Nuclear properties in this excitation-energy region are measured in term of statistical quantities such as the nuclear level density (NLD) and the radiative strength function (RSF).

The RSF represents the average γ-ray transition probability between states of a given energy difference and is one of the critical input parameters for calculating neutron-induced reaction cross-sections. Indeed it is relevant to the design of future and existing nuclear power reactors where sophisticated simulations strongly depend on evaluated nuclear data of the many nuclear reactions involved.

The Oslo nuclear physics group has developed a method to determine simultaneously the NLD and the RSF from particle-γ coincidence measurements [1, 2]. Several experiments have been carried out at the Oslo Cyclotron Laboratory (OCL) using light particle beams on various target materials.

Recently this method has been applied to measure NLD and RSF of gold isotopes. These experimental data can be useful for the analysis of neutron capture measurements performed at NIF (National Ignition Facility), California, USA [3]. Here a system of intense laser beams delivers up to 2 MJ on a target enclosed in a gold hohlraum causing the implosion of the fusion capsule. Then an intense neutron flux with a large sub-MeV component is produced. In this way one can reproduce the extreme temperature and density conditions in exploding stars.

This contribution aims at presenting the gold experiment results: ^{197}Au(d,p) and ^{197}Au(^{3}He,α) reactions have been studied using a 12.5 MeV deuteron beam and a 34 MeV alpha beam, respectively. NLD and RSF of ^{198}Au and ^{196}Au have been measured. In both nuclei a high spin ($J^{\pi}=12^{-}$) isomeric state is populated during the reaction. After-exposure radioactivity measurements have been done to estimate the isomeric yield ratios (IR's). Indeed the relative population of isomeric and ground levels depends on the emission mechanism (pre-equilibrium or evaporation emission). Recently, IR's have been measured also at NIF where highly-excited states in ^{196}Au populated via the ^{197}Au(n,2n) reaction might interact with the high energy density plasma environment in the hohlraum before γ-decay. This pre-equilibrium emission could impact the neutron capture rate in astrophysical plasmas relevant for heavy element nucleosynthesis.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Observation of new isomers in N=100 neutron-rich rare-earth nuclei

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Neutron-rich nuclei far from stability are fascinating since its isospin asymmetry sometimes gives rise to the drastic change of nuclear shapes and shell structure. In the double mid-shell regions such as neutron-rich rare-earth region, nuclei are known to be well deformed, and K isomers are often observed systematically. Significantly hindered transition could occur in the situation that the K quantum number is a good quantum number in the deformed system and the change of the K value exceeds the transition multipolarity [1]. The hindrance factor is very sensitive to the K-mixing mechanism such as rotational (Coriolis) mixing, vibrational mixing and the level density effect.

We observed new isomeric decays in the neutron-rich rare-earth isotopes, ^{162}Sm, ^{163}Eu, ^{164}Gd which have 100 neutrons by means of the isomer spectroscopy at the RIKEN RI Beam Factory. The nuclei were produced by the in-flight fission of ^{238}U at an energy of 345 MeV/nucleon with a ^{9}Be target of 4 g/cm^2 thickness. The intensity of the uranium beam was roughly 0.3 pnA. Fission fragments were separated using the BigRIPS separator [2] according to the mass-to-charge ratio (A/Q) and energy loss. Particle identification was performed event by event by measuring the magnetic rigidity ($B\rho$), time of flight (TOF), and the energy loss (ΔE) of the particle which were stopped in the stack of Si detectors. The isomeric γ-rays from excited nuclei were measured by four clover type Ge detectors closely surrounding the Si stack. The γ-ray was detected within the time window 30 μs following ion implantation.

We constructed the decay schemes for the first time based on the energy sum of the observed γ-rays as well as the relative intensities. From the observed decay schemes and reduced transition probabilities as well as the systematics of heavier $N = 100$ isotones, we interpreted these isomeric states to be characterized by the two-quasineutron configuration as $[1/2[521] \otimes 7/2[633]]$, $K = 4^-$. In this report the results of the observation of the new isomers, ^{162}Sm, ^{163}Eu, ^{164}Gd will be presented. We also discuss the evolution of nuclear shape and deformed shell structure based on our level schemes.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Why is Lead so Kinky?

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The kink in the charge radius shift of even-even nuclei near the $N = 126$ shell closure has been difficult to explain theoretically for several decades. Previous attempts have concentrated mainly upon the form of the nuclear interaction or the individual neutron orbital radius [1,2]. Most non-relativistic mean-field models struggle to reproduce the kink. We present a new explanation, advocating the influence of the $1i_{11/2}$ neutron orbital upon tightly bound $n = 1$ proton orbitals [3]. Skyrme-Hartree-Fock calculations demonstrate that Skyrme forces which induce a significant population of the $1i_{11/2}$ orbital for isotopes past the $N = 126$ shell closure reproduce the kink. Our conclusions are general around the $N = 126$ closure, with the mechanism applying to other nuclei in the lead region [4,5].

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Very neutron rich light nuclei and α-cluster states in neutron rich light nuclei.

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I'll present new experimental data on ^{9}He, and review the status of neutron rich ^{9}He, ^{10}He and ^{7}H. I'll also present new experimental data on α-cluster states in ^{10}Be and ^{18}O obtained by using the thick target inverse kinematics approach with rare beams, and I'll review the new possibilities opened by the studies of cluster states in $N \neq Z$ nuclei.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

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

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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 Δ_3 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 ^{24}Mg and ^{32}Na 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 regular quantum systems exhibit $1/f^2$ 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 $1/f^{\beta}$ 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.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

The Newly-Explored Region Beyond N=126 Reveals Unexpected Features of the Nuclear Structure

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The neutron-rich lead and mercury region has been so far scarcely explored due to its high mass and neutron excess, which force the use of fragmentation reactions with relativistic beams [1,2]. Neutron rich nuclei beyond ^{208}Pb were populated by using a 1 GeV/A ^{238}U beam at GSI. The resulting fragments were separated and analyzed with the FRS-RISING [3,4] setup. Many neutron-rich isotopes were identified for the first time and a significant number of new isomers were hence discovered, enabling us to study the structure of these isotopes. The new exotic isotopes observed extend up to ^{218}Pb 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 $^{212-216}$Pb, in ^{217}Bi, in ^{211,213}Tl and in ^{210}Hg. The isomers in $^{212-216}$Pb correspond to the expected seniority scheme [5], with an 8^+ isomer from neutrons coupling in the $2\nu g_{9/2}$ shell. The measured isomeric transitions rates show large discrepancies with shell-model estimates [5]. It is not uncommon that even large-scale shell-model calculations may fall short in reproducing the experimental data (as in the case of neutron-deficient tin isotopes). In the talk, it will be shown how the common but bad practice of neglecting effective three-body forces and two-body transition operators when calculating the B(E2) values could be the origin of the problems encountered [5,6].

Considering that the same 8^+ isomer was observed in ^{208}Hg [2], one would expect the two-proton hole Hg isotopes to follow the same scheme. On the contrary, the observed isomeric states in ^{210}Hg correspond to the expected seniority scheme and to an unexpectedly low-lying state, indicating a sudden change in nuclear structure with respect to ^{208}Hg. A similar situation happens in ^{211,213}Tl isotopes with respect to the standard seniority isomer observed in ^{209}Tl [2]. Therefore, the experimental data seem to suggest a modification of the expected nuclear structure in this scarcely-explored region of the nuclide chart. Several possibilities will be discussed, considering the systematics of electromagnetic transition rates and the predictions of shell model with realistic interactions.

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Semiclassical Description of a Single Particle Spectrum of a Nucleon in the Harmonic Oscillator Mean Field with Spin-Orbit Coupling

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We have presented the single particle spectrum for a particle in a mean field of isotropic harmonic oscillator with $\vec{l}.\vec{s}$ coupling based on our semiclassical approach. It has been seen that this spectrum, without $\vec{l}.\vec{s}$ coupling, exactly matches with the quantum mechanical one (without nuclear constraints). In this case, periodicity conditions give only pendulating orbits coinciding with $l=0$ axis, which fully support the observations reported by Bohr and Mottelson (Nuclear Structure (1975)). The orbits with $l \geq 0$ are generated by reflecting the particle from the nuclear surface, R_0, instead of infinity, which is the usual nuclear constraint. The mean field strength is fixed by the virial theorem. The resulting spectrum compares reasonably well with the quantum spectrum for a particle enclosed in a perfectly reflecting walls. The variation of particle number with energy help us to identify the significant quantum numbers $'n'$ and $'l'$ in this semiclassical method. Finally, the $\vec{l}.\vec{s}$ coupling splits each level and the splitting width of these levels compares well with that of nuclear splitting. Thus the complete nuclear shell model (with magic numbers) is reproduced without any fitting parameter.

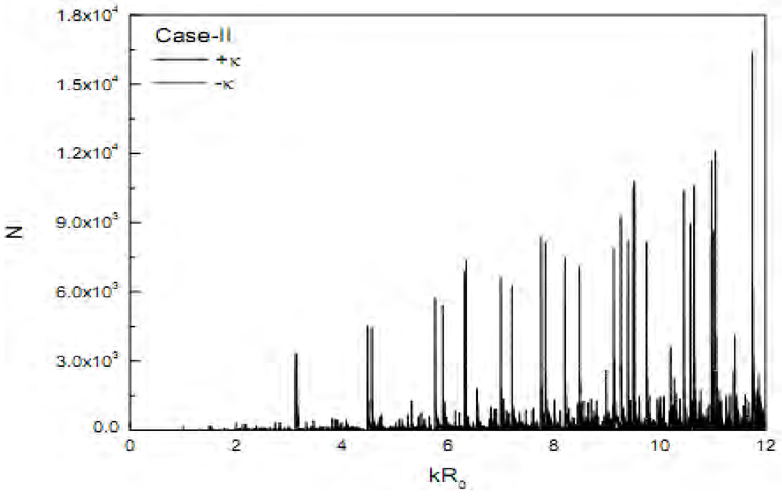

Figure 1: Particle number N vs. kR_0 for Case II including both positive and negative signs with κ in $\vec{l}.\vec{s}$ coupling.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Scissors Strength in the Quasi-Continuum of Actinides

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The orbital *M1-scissors* resonance has been measured for the first time in the quasi-continuum of actinides [1]. Particle-γ coincidences are recorded with deuteron and ^{3}He induced reactions on ^{232}Th at the Oslo cyclotron laboratory. The outgoing charge particles were measured in backward angles with the SiRi particle-telescope system. The γ-ray spectra were recorded for various excitation energies with the CACTUS system consisting of 28 5" x 5" NaI detectors.

The residual nuclei ^{231,232,233}Th and ^{232,233}Pa show an unexpectedly strong integrated γ-ray strength of *B(M1)* = 11-15 μ^2 in the 1.0 - 3.5 MeV γ-ray energy region. The results are comparable with maximum sum-rule estimates of about *B(M1)* = 15-17 μ^2 [2]. Figure 1 shows the scissors resonance for different excitation regions in ^{233}Th.

The presence of the strong scissors resonance has significant impact on (*n*, γ) cross sections. These cross sections have impact on fuel-cycle simulations of fast nuclear reactors and nucleosynthesis in explosive stellar environments.

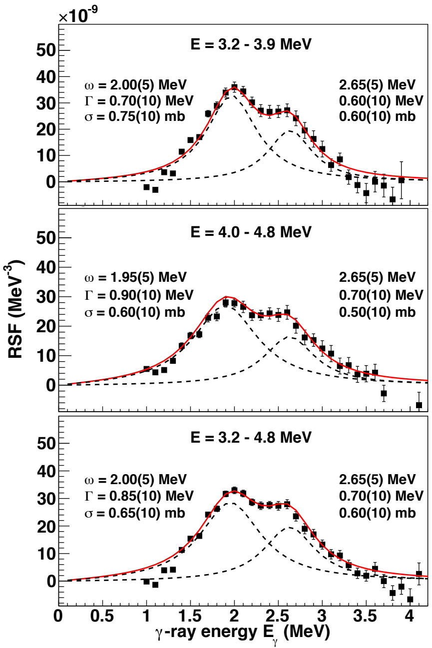

Figure 1: *The radiative strength functions (RSF) for ^{233}Th measured at different initial excitation energies. The data of the two upper panels are based on statistically independent data sets.*

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High-lying Gamow-Teller excited states in the deformed nuclei, ^{76}Ge and ^{82}Se, by the smearing of the Fermi surface in Deformed Quasi-particle RPA (DQRPA)

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(Dated: January 25, 2013)

With the advent of high analysis technology in detecting the Gamow-Teller (GT) excited states beyond one nucleon emission threshold, the quenching of the GT strength to the Ikeda sum rule seems to be recovered by the high-lying GT states. Moreover, in some nuclei, the stronger GT peaks than any other peaks appear explicitly in the high-lying excited states. We address that these high-lying GT excited states stems from the smearing of the Fermi surface by the increase of the chemical potential owing to the deformation within a framework of the deformed quasi-particle random phase approximation (DQRPA). Detailed mechanism leading to the smearing is discussed, and comparisons to the available experimental data are shown to explain the strong peaks on the high-lying GT excited states in a satisfactory manner.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Structure of ^{42}Ca Coulomb excited states

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The Coulomb excitation experiment to study electromagnetic properties of low-lying states in ^{42}Ca with a focus on a presumably super-deformed band was performed at the Laboratori Nazionali di Legnaro in Italy in 2010 using the gamma-ray spectrometer AGATA Demonstrator coupled to the DANTE charged particle detector array. Gamma-rays from Coulomb excited ^{42}Ca nuclei were measured in coincidence with calcium projectiles back-scattered on the ^{208}Pb and ^{197}Au targets and detected by three position-sensitive MCP detectors forming the DANTE array. The AGATA Demonstrator spectrometer consisting of three clusters was used for the first time in a nuclear physics experiment.

The motivation for the study was observation of a rotational structure in ^{42}Ca, which is similar to the previously identified super-deformed bands in several A~40 nuclei such as ^{40}Ca, ^{36,38,40}Ar, ^{44}Ti. Lifetime measurements in ^{42}Ca using the Doppler-shift attenuation method, suggest a smaller deformation of the band built on the second 0^+ state (1837 keV) than in the case of ^{40}Ca. On the other hand, the moment of inertia of this band was found to be very similar to the one of the super-deformed band in ^{40}Ca. Another argument for the highly-deformed character of this band was the observation of its preferential feeding by the low energy component of the highly split GDR decaying from ^{46}Ti.

In the present experiment the transitions de-exciting the highly deformed band were observed for the first time following the Coulomb excitation. Low lying states in the yrast band were also populated via multiple COULEX. It was possible to Coulomb excite levels of spin up to 6^+ in the ground state and up to 4^+ in the side band.

First surprising results have indicated some ambiguities concerning the interpretation of the known low-level structure of ^{42}Ca (K. Hadyńska-Klęk *et al.*, Acta Phys. Pol. B42, 817 (2011)). A dedicated fusion-evaporation experiment aiming at confirmation of the low spin level scheme in ^{42}Ca was performed in 2011 at Heavy Ion Laboratory, University of Warsaw, using the EAGLE spectrometer. Results of the additional measurement allowed to complete the first stage of the Coulomb excitation data analysis by determination of the B(E2) values, using the GOSIA code. Information on the deformation of the states in the ground state and side bands in ^{42}Ca were obtained by using the Quadrupole Sum Rules method approach.

Current status and results of the data analysis of both experiments will be presented, as well as the comparison with the large scale shell model predictions.

Advances in coupled-cluster computations of medium mass and neutron rich nuclei

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In this talk I will present recent advances in computing properties of nuclei using coupled-cluster theory. The beauty of coupled-cluster theory is that it can naturally account for: (i) effects of three nucleon forces, (ii) the presence of open decay channels and particle continuum, and (iii) many-nucleon correlations. Advances in chiral effective field theory allow for a systematic derivation of many-nucleon forces and currents, and provide us with a systematic approach to quantify uncertainties in computed observables in nuclei. Recently we optimized the nucleon-nucleon interaction from chiral effective field theory at next-to-next-to leading order (NNLO) using the mathematical optimization software POUNDerS (Practical Optimization Using No Derivatives for Squares), obtaining a $\chi^2 \approx 1$ for laboratory energies below 125MeV [1]. We demonstrated with this optimized interaction, that several key aspects of nuclei can be understood without explicitly invoking three-nucleon forces. Other recent highlights include ab-initio coupled-cluster calculation of the giant dipole resonance in ^{16}O [2], coupled-cluster calculations of oxygen and calcium isotopes, with an emphasis on the evolution of shell structure. In particular we address the question regarding shell closure in ^{54}Ca [3].

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Structure of the nuclei with $Z \sim 100$ investigated by a particle-number conserving method based on a cranked shell model

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Nuclei with $Z \sim 100$ in the transfermium mass region are the heaviest systems accessible in present in-beam experiments. Transfermium nuclei are at the gateway to the superheavy elements (SHE) region. The study of these deformed transfermium nuclei may provide an indirect way to access the single particle states of the next closed spherical shells (see the review [1-3] and references therein).

The structure of the very heavy nuclei with $Z \sim 100$ are investigated systematically by the cranked-shell model (CSM) with pairing correlations treated by a particle-number conserving (PNC) method [4]. In the PNC method, the particle number is conserved and the Pauli blocking effects are taken into account exactly. By fitting the experimental single-particle spectra in these nuclei, a new set of Nilsson parameters (κ and μ) are proposed [5]. The experimental kinematic moments of inertia and the band-head energies are reproduced quite well by the PNC-CSM calculations. The structures of the single-particle states, closed sub-shell effects, deformation, pairing correlation, rotational properties, high-j intruder orbital and high-K multi-quasiparticle states in these transfermium nuclei are studied in detail [5-7].

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Nuclear Structure Studies by Means of (p,p$'\gamma$) Experiments

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The method of inelastic proton scattering will be presented by focusing on two experiments which were performed at WNSL, Yale University. Both experiments used the YRAST-ball spectrometer for γ-ray detection and a target chamber that housed five silicon detectors for charged-particle spectroscopy. Since the coincident detection of the scattered proton and the de-exciting γ-ray yields information on the excitation energy as well as on the transition energy this method is especially useful to determine very small γ-decay branching ratios [1].

The nucleus ^{96}Ru was studied to investigate mixed-symmetry states. While the $2^+_{1,\mathrm{ms}}$ has been identified by the measurement of the absolute M1 transition strength to the 2^+_1 [2,3], the assignment of the J^π=2^+ and 3^+ members of the two phonon mixed-symmetry states is based on the comparison of the γ-decay patterns to the neighbouring even-even N=52 isotone ^{94}Mo [2]. To gain further experimental evidence for the assignment of the mixed symmetry character of those states, like branching ratios and multipole mixing ratios, a resonant proton-scattering experiment has been performed.

In a second experiment octupole vibrational states in the nucleus ^{150}Nd were investigated by measuring B(E1)-strength ratios of the de-exciting transitions of negative parity states [4]. From these ratios, K quantum numbers could be assigned by comparison to the Alaga rule.

Those experiments have proven, that (p,p$'\gamma$) experiments are a powerful method to gain information on manifold aspects in nuclear structure physics. To be able to perform this kind of experiments with the 10MV Tandem accelerator at the Institute for Nuclear Physics in Cologne, a new target chamber SONIC has been designed, housing up to eight ΔE-E silicon detectors. The chamber can be embedded within the existing γ-ray spectrometer HORUS, which allows to detect scattered charged particles in coincidence with the deexciting γ-rays. The design and results of first test experiments with the new target chamber will be presented as well.

Supported by the DFG under contract (ZI-510/4-2) and US DOE Grant No. DE-FG02-01ER40609. AH is member of the Bonn-Cologne Graduate School of Physics and Astronomy.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Exploring the stability of super heavy elements

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Super heavy nuclei exist solely due to quantum shell effects, which create a pocket in the potential-energy surface of the nucleus, thus providing a barrier against spontaneous fission. Determining the height of the fission barrier and its spin dependence $B_f(I)$ is therefore important to quantify the role that microscopic shell corrections play in enhancing and extending the limits of nuclear stability. It is also valuable for understanding the formation mechanism of heavy nuclei since these nuclei are generally produced at high spin in fusion-evaporation reactions.

The gamma-ray multiplicity and total energy of the heavy shell-stabilized nucleus ^{254}No produced in the reaction ^{208}Pb(^{48}Ca,2n) have been measured for beam energies of 219 and 223 MeV at the Argonne Tandem Linac Accelerator System. The ^{254}No gamma rays were detected using the Gammasphere array as calorimeter. Coincidences with the detection of fusion-evaporation residues at the focal plane of the Fragment Mass Analyzer separated ^{254}No gamma rays from those emitted by fission fragments and other reaction products, which are more than a million times more intense.

From this measurement, the initial distribution of spin I and excitation energy E^* of ^{254}No was constructed for both bombarding energies. Each point (I,E^*) of this entry distribution is a point where gamma decay wins over fission. The distributions display a saturation in excitation energy, which allows a direct determination of the fission barrier [1].

This is the first time the height of a fission barrier is measured for a nucleus heavier than Cf. This result is compared to theoretical predictions [2-6] and to the situation in ^{220}Th, with 12 protons less, studied in a similar manner.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Spectroscopy of light bismuth isotopes

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Two different in-beam γ-ray experiments were performed at the Accelerator laboratory of the University of Jyväskylä in order to investigate in detail the structure of the neutron deficient nuclei ^{193,194,195}Bi. The bismuth nuclei were produced in a fusion-evaporation reactions employed at various beam energies. Fully digitized JUROGAM II γ-ray spectrometer coupled with the gas-filled high-transmission recoil separator RITU [1,2] and the digitized GREAT focal plane spectrometer system allowed for using the very selective recoil-decay tagging, isomer tagging and recoil gating techniques.

Concerning the ^{193}Bi isotope, many new γ-ray transitions from the excited states have been observed so far, extending the level scheme to higher spin states. Moreover, an extension of the band built on top of the $\frac{1}{2}^+$ proton intruder state [3] has been observed.

In case of ^{194,195}Bi isotopes, both thick and thin target experiments have been recently performed, allowing us to extend the so far very limited information [4,5] on the feeding patterns and population of the regular and rotational bands, respectively. In ^{195}Bi, the rotational band built on top of the $\pi i_{13/2}$ isomeric state has been established. Furthermore, the preliminary analysis of the focal plane data allowed an identification of the two delayed cascades decaying to $\frac{9}{2}^-$ ground state, together with additional not-delayed negative parity band.

In all three bismuth isotopes an indication of new short-lived isomeric states appears. The information we get from these studies is essential as the bismuth isotopic chain has only one extra proton coupled to the magic proton $Z = 82$ lead core, giving us the opportunity for detail investigation of the one-particle level evolution, coupling strenghts and its effect on the shape co-existence as well as many other yet unsolved topics.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Nuclear Structure of the Heaviest Elements Investigated at SHIP - GSI

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The quest for the heaviest nuclei that can exist is a basic topic in natural science as their stability is characterized by a delicate interplay of short range nuclear forces acting between the nucleons (protons and neutrons) and long-range Coulomb forces acting solely between charged particles, i.e. the protons. In this sense understanding nuclear stabilitity and its limits at the upper part of the charts of nuclei ($Z > 100$) is essential to understand basic interactions. As the stability of a nucleus is strongly correlated to its structure, understanding the nuclear structure of heaviest nuclei is presently - besides synthesizing new elements - the main challenge of experimental and theoretical investigations concerning the field of Superheavy Elements (SHE).

At GSI Darmstadt an extensive program on nuclear structure investigations by means of α-γ – or α – conversion electron (CE) spectroscopy of nuclei collected in the focal plane of the velocity filter SHIP has been started about a decade ago. The project covered both: systematic investigations of single particle levels populated by α-decay in odd-mass isotopes (see e.g. [1,2,3]) as well as investigation of two- or four-quasi-particle states forming K isomers (see [4,5,6]). In addition, first results on nuclear structure from EC decay using K X-ray – γ – and γ – γ – coincidence measurements were obtained [6].

The studies were supplemented by direct mass measurements at SHIPTRAP [7] and investigation of spontaneous fission properties.

Results obtained in the element region $Z = 99$ to $Z = 110$ and also their relevance for the spontaneous fission process and expected properties of SHE at $Z > 112$ will be presented and discussed within theoretical frameworks.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Complete Spectroscopy of Negative Parity States in $^{208}\mathrm{Pb}$ with $\mathrm{E_x} \lesssim 6.5\,$MeV

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The study of the doubly magic nucleus ^{208}Pb is of key interest as more and more doubly magic nuclei come into the reach of modern experiments. The schematic shell model without residual interaction (SSM [1]) predicts 70 particle-hole states with negative parity for $E_x^{SSM} < 6361$ keV (Fig. 1, left panel). Recent experiments revealed new identifications, new spin and parity assignments for many states [1]. The main source of information comes from the study of the inelastic proton scattering on ^{208}Pb via isobaric analog resonances (IAR) in ^{209}Bi. Additional data is known [2], especially for the ^{207}Pb(d,p) reaction. The excitation of the states by these two reactions is highly selective; they excite only certain neutron particle-hole configurations in each state. In Fig. 1 neutron and proton configurations are marked by solid and dotted lines, respectively. Experiments on the ^{208}Pb(p,p') and ^{207}Pb(d,p) reactions have been performed with the Q3D magnetic spectrograph of the Maier-Leibnitz-Laboratorium at München at an energy resolution of 3 keV FWHM. The ^{208}Pb(p,p') reaction via an IAR LJ in ^{209}Bi is equivalent to the neutron pickup reaction on a target of ^{209}Pb in an excited state LJ. In each state of ^{208}Pb, It excites the components $LJ^{+\nu} \otimes lj^{-\nu}$ with a neutron hole lj and a neutron particle LJ. The sum rules for 64 out of 70 particle-hole configurations with spins 0^-- 8^- are thus found to be complete within 10%; the completeness of six not directly detectable configurations (built with the $f_{5/2}^{+\pi}$ proton) is deduced. The presence of a large gap in the SSM space at $6033 \le E_x^{SSM} < 6361$ keV together with the determination of the configuration mixing in all 70 states allows to deduce matrix elements of the residual interaction [3].

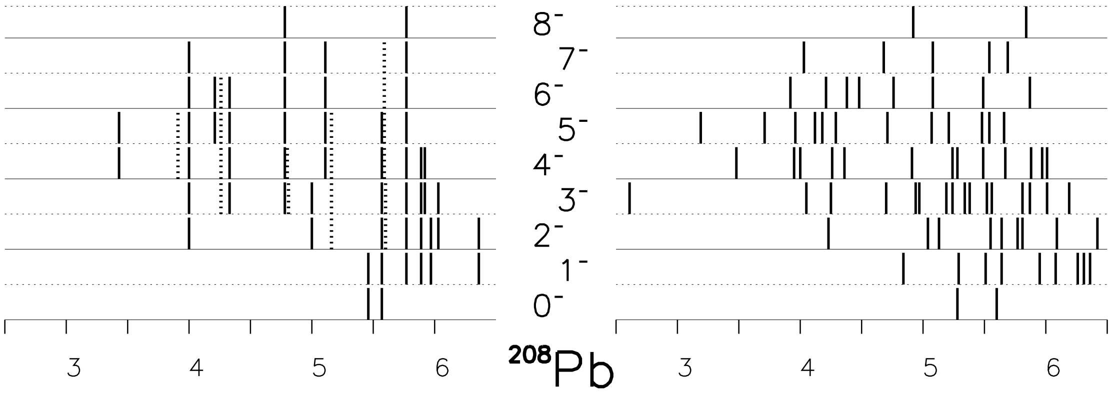

Figure 1: (left) *SSM configurations,* (right) *identified states with spins* 0^-- 8^- *and* $2.5 < E_x \lesssim 6.5$ MeV.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Shell model description of high spin isomers in Po and Rn isotopes

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Low-lying states in the light actinide region are successfully interpreted in terms of a few valence particles in shell model configurations. For example, the measured magnetic moments of the isomeric 8_1^+ states in $^{206-214}$Rn were confirmed to be assigned as a proton $(0h_{9/2})^4$ configuration [1]. The low-lying near-yrast states were analyzed in terms of the interacting boson model plus two quasi-particles model [2], where one of the bosons is replaced by a pair of nucleons at high spin. A good agreement with experiment was achieved for both the energy spectra and electromagnetic transitions.

In this work, the band structures of the Po and Rn isotopes are studied in terms of the full-fledged shell model. The monopole and quadrupole pairing plus quadrupole-quadrupole interaction is employed as an effective interaction. As for single-particle levels, all the six orbitals, $0h_{9/2}$, $1f_{1/2}$, $0i_{13/2}$, $1f_{5/2}$, $2p_{3/2}$, and $2p_{1/2}$, in the major shell between the magic numbers 82 and 126 are taken into account for both neutrons and protons. The calculation reproduces well the experimental energy levels and electromagnetic transitions of high-spin states as well as low-lying collective states.

In order to investigate collective behavior at low energies and the effect of the single particle excitations at high spins, the energy spectra in the shell model are compared with those in a pair-truncated shell model (PTSM) [3,4]. The building blocks of this model are angular momenta zero (S), two (D) and four (G) collective pairs, and also non-collective pairs. The Hamiltonian in this truncated space (PTSM space) is set identical to that used in the shell model. We analyze the structure of the high-spin states and low-lying collective states through the PTSM wave functions. The theoretical results will be presented and discussed in this conference.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Application of the generator coordinate method to neutron-rich Se and Ge isotopes

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The intriguing properties of the even-even Se and Ge isotopes in the mass A ~ 80 region were studied in a number of previous experimental and theoretical works [1]. These isotopes belong to a typical transitional region between spherical and deformed regions. The structure of their low-lying states can be understood as arising from the interplay of rotational and vibrational collective motions. For high spin states, γ-ray spectroscopy of near-yrast states in the $N = 44$, 46 isotones ^{80,82}Se was studied using deep inelastic reactions [2]. Recently, shell-model calculations have been performed for the even-even and odd-mass nuclei in this mass region [3]. The shell model calculations reproduce well the experimental energy levels and electromagnetic transition rates for the low lying and high-spin states.

In the present study, we apply the quantum-number projected generator coordinate method (PGCM) to Se and Ge isotopes under the same circumstances as in the previous shell model studies [3]. All the relevant orbitals, $0g_{9/2}$, $1p_{1/2}$, $1p_{3/2}$, and $0f_{5/2}$, in the major shell between the magic numbers 28 and 50 are taken into account for both neutrons and protons. PGCM calculations are performed for two cases: (i) triaxial deformations with $\beta = 0.05$, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, and $\gamma = 10°$, 20°, 30°, 40°, 50° (30 points); (ii) only axial deformations with $\beta = 0.00, 0.02, 0.04, \ldots, 0.60$ and $\gamma = 0°, 60°$ (61 points). In Fig 1, energy spectra calculated for the cases (i) and (ii) are compared with experimental data, and also with the shell model results for ^{78}Ge. In both cases, the PGCM reproduces well the energy levels of the even-spin yrast band. As for the other excited states, the PGCM calculations assuming the triaxial deformation are in good agreement with the shell model results, especially for the 2_2^+, 3_1^+, 4_2^+ and 5_1^+ states, which are members of the γ band. However, assuming only the axial deformation the 2_2^+, 3_1^+ and 5_1^+ states appear higher in energy than the shell model ones. Apparently the restriction to axially symmetric shapes does not work well for the description of the 2_2^+, 3_1^+, 4_2^+ and 5_1^+ states. The triaxial components play essential roles in describing these states. The results of this calculation will be presented and discussed in this conference.

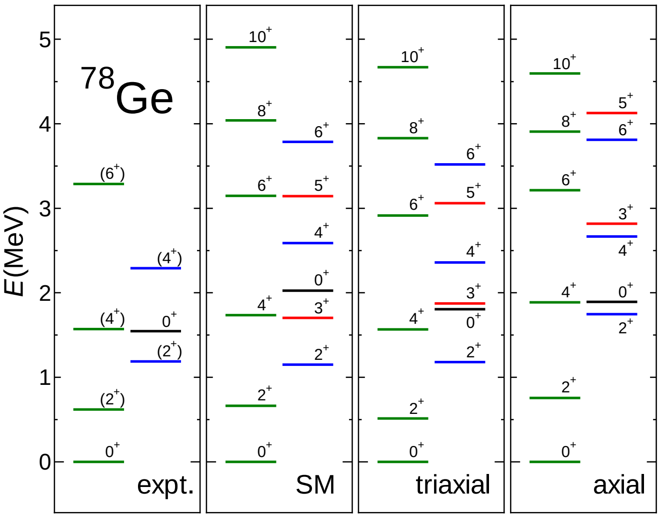

Figure 1: *Energy levels of the yrast and quasi-γ bands in ^{78}Ge. From the left, energy levels in the experiment (expt.), the shell model (SM), the axial PGCM (axial), the triaxial PGCM (triaxial) are displayed.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Tensor correlations probed by electroweak responses

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Nuclear response functions for electroweak interactions provide us with important information on the resonant and continuum structure of the nuclear system as well as the detailed property of the underlying interactions. In this contribution, we present our recent study on the electroweak response functions with realistic nuclear forces and discuss their relation to tensor correlations in the ground state.

Recently the present authors and Arai have presented an *ab initio* calculation for the photoabsorption of ^{4}He [1]. In the energy region around 26 MeV, photoabsorption reaction occurs mainly through the electric dipole transition. The paper shows that the experimental data above 30 MeV is reproduced very well, and the one-pion-exchange terms in the nucleon-nucleon potential, especially the tensor term, are essential in accounting for the energy-weighed sum rule. We extend the discussion to the spin-dipole response function. Since the operator can change the spin wave function of the ground state, a study of the spin-dipole response functions is expected to be more advantageous than that by the electric-dipole one. The study is also interesting as its importance for the scenario of a supernova explosion. In the final stage of a core collapse supernova, ^{4}He is exposed to intense flux of neutrino. The ν-^{4}He reaction is expected to play a significant role, and the reaction rate is proportional to the weak responses, for example, due to Gamow-Teller, spin-dipole, etc. operators.

A reliable method is needed to describe above mentioned electroweak reactions. In this study, we calculate the response functions based on a full four-body calculation with realistic nuclear forces. The wave functions are approximated in a combination of explicitly correlated Gaussians reinforced with a global vector representation for the angular motion [2,3]. Final state interactions and two- and three-body decay channels are taken into account. The excited states of ^{4}He are all in the continuum and are treated properly with the complex scaling method.

The observed resonance energies and widths of the negative-parity levels are all in fair agreement with those calculated from both the spin-dipole and electric-dipole strength functions. Spin-dipole sum rules are discussed in relation to tensor correlations in the ground state of ^{4}He [4]. Possible observables are suggested to probe the tensor correlations in the ground state.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Unified description of shell and cluster coexistence in ^{16}O with a five-body model

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In this contribution, a famous and long-standing problem so called a mysterious 0^+ state in ^{16}O is discussed. In contrast to the shell-model like ground state, the first excited 0^+ state is known to have a cluster structure of ^{12}C+α [1], which indicates the coexistence of different structure in the spectrum but have not been reproduced microscopically even in modern large scale calculations. A unified description is desired for its deep understanding. Since a fully microscopic calculation is not feasible at present, it is interesting to study ^{16}O with a ^{12}C core plus four-nucleon model, that is without assuming the α cluster.

The five-body wave function is expressed by a linear combination of the correlated Gaussians reinforced with two global vectors [2]. An advantage of this method is that its functional form does not change under any coordinate transformation, and thus both cluster- and shell-model like configurations can be expressed in a single scheme. The ^{12}C$-N$ potential is prepared so as to reproduce the low-lying spectrum of ^{13}C. The orthogonality constraint for the relative motion is imposed in order to take the Pauli principle into account. An optimal solution is obtained following the stochastic variational method [3].

The left panel of Figure 1 displays the calculated energy curves of the ground (0_1^+) and first excited (0_2^+) states of ^{16}O as a function of the number of basis functions. It is found that the 0_1^+ state appears below the ^{12}C+α threshold and the 0_2^+ state appears just at a few MeV from the ground state, consistently with experiment. The middle and right panels of Fig. 1 display the expectation values of the ^{12}C$-N$ (C$-N$) and the nucleon-nucleon ($N-N$) potentials acting among the valence nucleons. For the 0_1^+ state, we expect a phase transition from the cluster structure to shell-model like structure in 4000 to 6000 basis states where the total energy crosses over the ^{12}C+α threshold. Finally, the $N-N$ energy is approximately half of the $N-N$ contribution of the free alpha particle (-88.03 MeV) obtained with the same $N-N$ potential [2]. The α particle is distorted by attraction of the core nucleus as well as the Pauli constraint, however, in the case of the first excited state of ^{16}O, the $N-N$ contribution is dominant and is very close to that of the free alpha particle. This suggests that the first excited state has a well developed ^{12}C+α structure as predicted by the cluster model [1]. To make it more quantitative, we will discuss the spectroscopic amplitude (factor) of ^{12}C+α to investigate the cluster degree in the spectrum.

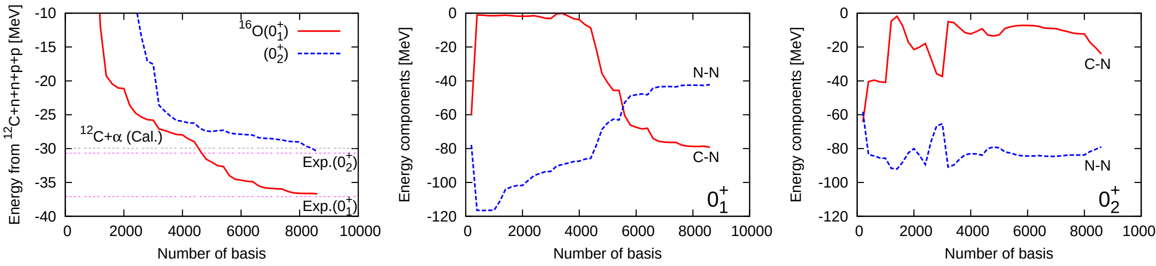

Figure 1: *Calculated energy curves for the ground (0_1^+) and first excited (0_2^+) states of ^{16}O and their C$-N$ and $N-N$ components as functions of basis dimensions.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Coulomb excitation of the band-terminating 12^+ yrast trap in ^{52}Fe

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In the last decade the $1f_{7/2^-}$ shell nuclei have become a very successful test area for nuclear models and interactions. Near the middle of the shell, nuclei show collective properties similar to those observed in heavier nuclei, such as rotational-like bands, band termination, and backbending phenomena. Presently this is the unique region where it is possible to describe deformed nuclei within both the mean-field and the shell-model descriptions [1,2].

The ^{52}Fe nucleus (N=Z=26), with two proton and two neutron valence holes in the doubly magic ^{56}Ni, has been a particular experimental challenge. Many attempts to extend the ^{52}Fe level scheme have failed due to the presence of a 12^+ isomer, which acts as a "trap" for the de-exciting γ-ray flux, thus ^{52}Fe is known up to the 12^+ state [3,4].

The present work aims to investigate the structure and in particular the collectivity of the 12^+ by performing relativistic Coulomb excitation of a ^{52}Fe 12^+ isomeric beam. The experimental activity has been performed within the AGATA-PRESPEC campaign at GSI.

The ^{52}Fe 12^+ isomer was produced by the fragmentation of a ^{58}Ni primary SIS beam at 500MeV/u. The ^{52}Fe fragments were selected with the FRS setup and finally hit the ^{197}Au secondary target.

The use of FRS allowed the selection of high momentum part of the secondary beam distribution in order to maximize the isomeric ratio, known to be larger than 10%.

The analysis of the experiment is still on-going, and the excitation of ^{52}Fe g.s. has been already observed. Preliminary results of the experiments will be presented in this contribution

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Magnetic moment measurement in ^{72}Zn using the Transient Field technique and Coulomb excitation in inverse kinematics

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Nuclear magnetic moments are sensitive probes of the single particle properties of the nuclear wave function. The magnetic moment operator, with its explicit dependence on protons or neutrons involved in the configuration of the state and on their angular momenta, serves as a stringent test of the proposed main configuration of the nuclear state, as well as of other admixtures. It is, therefore, necessary to study nuclear magnetic moments of nuclei that lie close to nuclear shell closures or, in general, to any place on the nuclear chart where the valence nucleons start filling a higher lying orbital in the next major shell. A good example is provided by the N = 40 region around ^{68}Ni on the neutron-rich side of the nuclear chart, where the positive parity $\nu g_{9/2}$ orbital dives into the negative parity *fp* shell. It is a long standing issue whether N = 40 has to be considered as a new (sub)shell closure or whether the peculiar effects observed in the region can be traced back to the parity change between $\nu g_{9/2}$ and the *fp* shell which prevents 1p1h states from contributing to the wave functions of positive parity states.

In an experiment performed at REX-ISOLDE in November 2011, the g factor of the first excited 2^+ state in ^{72}Zn, $g(2_1^+)$, was measured using the Transient Field (TF) technique in combination with Coulomb excitation in inverse kinematics and two different thick multilayer targets. This technique has been successfully employed in the past in a large number of stable ion beam experiments [1]. However, only recently it was applied for the first time using low-energy radioactive ion beams at Oak Ridge [2,3].

This contribution will cover different aspects of the performed experiment. First we will present the newly constructed transient field reaction chamber adapted to the special needs of TF measurements with short-lived radioactive beams. Then we will report on the experimental details and the data analysis procedure with a special emphasis on the advantages of the employed setup in this respect. Finally, we will discuss the experimental result in the context of the systematics in this region of the chart of nuclides and compare it to a number of different large-scale shell model calculations.

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Decay pattern of the Pygmy Dipole Resonance in ^{130}Te

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The isovector electric dipole strength ($E1$) in atomic nuclei has been investigated intensively in the last decades, especially in the region of the Giant Dipole Resonance (GDR) [1]. However, for many nuclei additional low-lying $E1$ strength below and in the vicinity of the particle separation energies have been observed, which is usually denoted as Pygmy Dipole Resonance (PDR) [2]. The properties of the PDR have been mostly studied in closed-shell nuclei, e.g. in the Z=50 and N=82 mass region [2]. To extend the systematic of the PDR to open-shell nuclei Nuclear Resonance Fluorescence (NRF) experiments were used to investigate the electric dipole response in ^{130}Te. The first experiment has been performed at the Darmstadt High Intensity Photon Setup (DHIPS) [3]. By using bremsstrahlung as a photon source the absolute dipole transition strength up to the neutron separation energy at 8.4 MeV has been determined. Between 6 and 8 MeV a resonance-like structure has been observed. However, this experiment is not sensitive to the character of these dipole transitions. Therefore, an additional NRF experiment with mono-energetic and linearly polarized photons has been performed at the High Intensity γ-Ray Source (HIγS) [4] at the Duke University, USA. Due to the linear polarization of the photons it is possible to access parity information of the excited J=1 states and hence one can distinguish between $E1$ and $M1$ strength. In addition, the mono-energetic character of the photons allows for investigating the average decay properties of the dipole excited states as a function of the excitation energy [5]. The combined results of both NRF experiments provide an extensive overview of the $E1$ strength distribution in ^{130}Te up to the neutron separation energy. The comparison of the experimental results to simulations in the framework of the statistical model using the DICEBOX code [6] show an interesting and new insight in the photon-strength functions involved. The results are presented and discussed.

*This work was supported by the Alliance Program of the Helmholtz Association (HA216/EMMI) and by the Deutsche Forschungsgemeinschaft (SFB 634 and SO907/2-1).

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Unified studies of neutron-excess systems from bound to continuum

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In light neutron-excess systems, many kinds of molecular structures are discussed from the view point of the clustering phenomena. In particular, much attention has been concentrated on Be isotopes. The molecular orbital (MO) around the ^{8}Be (=α+α) core, such as π^- and σ^+ associated with the covalent binding of atomic molecules, have been shown to give a good description for the low-lying states of these isotopes [1]. In their highly-excited states, furthermore, recent experiments revealed the existence of the interesting resonant states which dominantly decay to the ^{6,8}He fragments [2]. In this report, we show the unified study of the exotic cluster structures of even Be isotopes (=α+α+XN, X=2,4,6,8) from bound states to continuum.

We applied the generalized two-center cluster model (GTCM), in which the formations of various chemical bonding structures, such as covalent MOs and the atomic orbital (AO) configurations with ^{x}He+^{y}He, can be described in a unified manner [3,4]. Due to the consistent treatment of chemical bonding structures, this model can also describe the nuclear reactions from AOs to MOs, which are observed in continuum above particle-decay thresholds [4]. An example of ^{14}Be= α+α+6N is shown in Fig. 1.

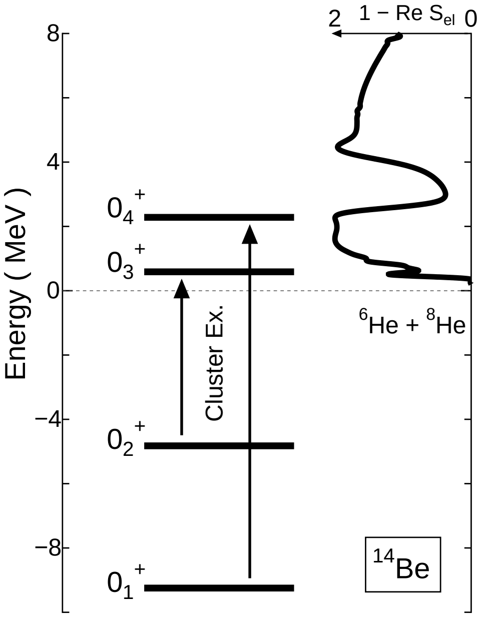

Figure 1: *J^π=0$^+$ energy levels in ^{14}Be. The curve above the zero energy show the total reaction cross section in the collision of ^{6}He$_{g.s.}$+^{8}He$_{g.s.}$. Two arrows represent the cluster excitations from the bound states.*

First, we solved the bound state problem, and two energy levels are obtained (0_1^+ and 0_2^+). Next, we solved the scattering problem of ^{6}He+^{8}He and identified resonance states, which are embedded in the scattering matrix (a curve in the right side of Fig. 1). In the continuum region, we found that the 0_3^+ and 0_4^+ states correspond to the cluster excitation mode from the bound states, 0_2^+ and 0_1^+, respectively. Specifically, these two resonances are generated by the excitation of relative motions between two α-cores in the two bound states. As a result of a cluster excitation, the AO structures, such as ^{6}He$_{g.s.}$+^{8}He$_{g.s.}$ and ^{6}He*+^{8}He$_{g.s.}$, are developed in the 0_3^+ and 0_4^+ states, respectively.

We performed the similar calculations for other Be isotope ($^{8\sim16}$Be) and confirmed that “the nuclear dimer of ^{6,8}He”, such as ^{10}Be=α+^{6}He, ^{12}Be=^{6}He+^{6}He and α+^{8}He, ^{16}Be=^{8}He+^{8}He are realized in the excited states embedded in continuum. Systematics of ^{6,8}He-dimer structures in Be isotopes is discussed, and further studies of the heavier neutron-excess systems, such as ^{18}O and ^{28}Ne, will also be presented.

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Candidate for the linear-like 3α cluster state in ^{12}C

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The ^{12}C nuclues is one of nuclei in which the cluster structure clearly appears in the nuclear excitation. Especially, the 0^+ state at 7.65 MeV in ^{12}C is a typical one which has a character of the 3α cluster structure. According to the microscopic α-cluster models, this state is considered to have a 3α gas-like structure in which 3α clusters are weakly coupled. About ten years ago, Tohsaki *et al* showed this 3α gas-like structure was similar to the Bose-Einstein condensate of the 3α clusters by using the condensate model wave function [1].

In our previous studies, the 2^+ state at 9.84 MeV with a width of 1.1 MeV was found by the multipole decomposition analysis (MDA) of the angular distribution of inelastic α scattering at 386 MeV [2]. Recently, it was identified with the 2^+ state at 9.75 MeV found by inelastic proton scattering [3]. From the ^{12}C(γ,3α) experiment at High Intensity Gamma-Ray Source (HIGS), the 2^+ strength at around 10 MeV also has been measured [4]. Therefore, the 2^+ state at 10 MeV was almost established. This supported to the 3α gas-like structure.

The result of the MDA also indicates the broad 0^+ state at 10 MeV consists of two components, the 9.0 MeV and the 10.6 MeV states [2]. In order to study structures of the excited states around 10 MeV in ^{12}C further, we investigated decay properties of these states by the ^{12}C(α,α')^{12}C*[α + X] reaction. The angular correlations for decay α particles were consistent with the result of the MDA. We found additional evidence that the broad 0^+ state at 10 MeV consists of two components from the decay-α measurement. The lower 0^+ component has a decay channel to the ground state of ^{8}Be. If the 2^+ state at 9.84 MeV has a strong coupling to the recently found 4^+ state at 13.3 MeV [5] as a member of a rotational band of the ground state of ^{8}Be + α cluster, the band head 0^+ state appears at $E_x \sim$ 8.5 MeV. For that reason, the lower 0^+ component is inferred to be the band head of the ground state of ^{8}Be + α cluster structure. On the other hand, the higher 0^+ component decay mainly to the 2^+ state of ^{8}Be channel. The linear-like 3α cluster state predicted by the AMD calculation [6] is expected to decay to the 2^+ state of ^{8}Be channel. Therefore, the higher 0^+ component could be the linear-like 3α cluster state.

In this contribution, the details of our experiment and analysis will be presented in comparison with the results from other experiments.

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Spectroscopic factors from the $^{111}\mathrm{Cd}(\vec{\mathrm{d}},\mathrm{p})^{112}\mathrm{Cd}$ single neutron transfer reaction

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The cadmium isotopes have been cited as excellent examples of vibrational nuclei for decades, with multi-phonon quadrupole, quadrupole-octupole, and mixed-symmetry states proposed. From a variety of experimental studies, a large amount of spectroscopic data has been obtained, recently focused on γ-ray studies. In the present work, the single-particle structure of ^{112}Cd has been investigated using the $^{111}\mathrm{Cd}(\vec{\mathrm{d}},\mathrm{p})^{112}\mathrm{Cd}$ reaction. The high energy resolution investigation was carried out using a 22 MeV beam of polarized deuterons obtained from the Maier-Leibnitz Laboratory at Garching, Germany. The reaction ejectiles were momentum analyzed using a Q3D spectrograph, and 130 levels have been identified up to 4.2 MeV of excitation energy. Spin-parity assignments have been made for each analyzed level, and angular distributions for the reaction cross-sections and analyzing powers were obtained. Optical model calculations have been performed, and the calculated angular distributions were compared with the experimental cross-sections and analyzing powers. Many additional levels have been observed compared with the previous (d,p) study performed with 8 MeV deuterons, including strongly populated 5^- and 6^- states. The former was previously assigned as a member of the quadrupole-octupole quintuplet, based on a strongly enhanced B(E2) value to the 3^- state, but is now re-assigned as being predominately $\mathrm{s}_{1/2} \otimes \mathrm{h}_{11/2}$ two-quasineutron configuration.

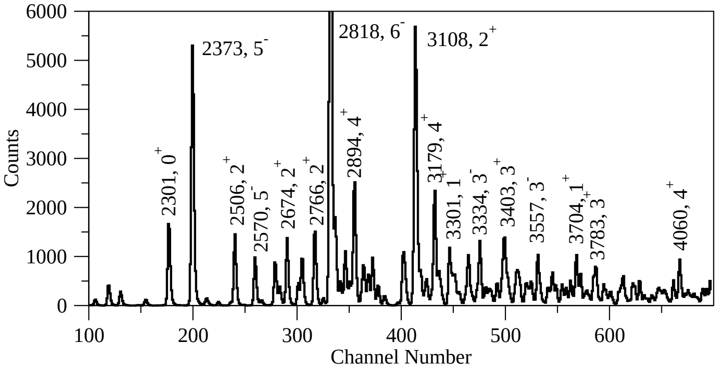

Figure 1: *Spectrum from 2.0 MeV to 4.2 MeV of states populated in the* $^{111}\mathrm{Cd}(\vec{\mathrm{d}},\mathrm{p})^{112}\mathrm{Cd}$ *single neutron transfer reaction*

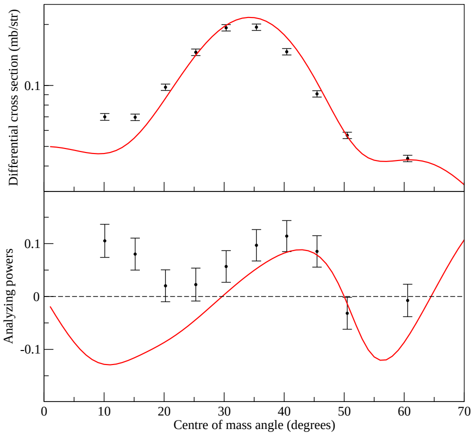

Figure 2: *Angular distribution of cross sections and analyzing powers for the 2373 keV* 5^- *state, with* $h_{\frac{11}{2}}$ *ADWA optical model calculation shown*

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Study of shape transition in the neutron-rich Os isotopes

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G. Pollarolo[12], F. Recchia[1], O.J. Roberts[7], E. Şahin[2], M.-D. Salsac[9], F. Scarlassara[1], M. Sferrazza[13],
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The nuclei with A∼190 between Hf and Pt exhibit a great variety of nuclear phenomena, including K-isomerism, triaxiality and shape transition across the isotopic chain. This region has been in fact a crucial testing ground for the nuclear models aspiring at the description of such complex nuclear phenomena. Of particular interest is the transition from axially symmetric deformed, prolate ($\gamma = 0°$) to oblate ($\gamma = 60°$) shapes in the neutron-rich Os isotopic chain. While a study by Wheldon et al. [1] of the neutron-rich ^{194}Os nucleus populated via deep-inelastic reactions suggests a prolate shape for its yrast states, Podolyák et al. [2] proposed an oblate shape for the ground state of ^{198}Os by comparing the excitation energies of the first and second 2^+ states. The ground state of ^{198}Os, the even-even isotope lying between the two previously mention ones, is predicted to be prolate, oblate or gamma-soft by different state-of-the-art nuclear models. This region of the Segre chart is very difficult to study experimentally, only fragmentation and multi-nucleon-transfer reactions can be used to populate neutron-rich nuclei in this region, hence knowledge for this nucleus is limited to two excited states without any known transition [3]. To further elucidate this shape transition, the key nucleus ^{196}Os was investigated in-beam using the AGATA demonstrator [4, 5] and the large acceptance heavy ion spectrometer PRISMA [6] at LNL, Italy. A two nucleon transfer from a ^{198}Pt target to a stable ^{82}Se beam was utilised to populate medium-high spin states of ^{196}Os. Preliminary results will be presented.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

A Study of Empirical Mass Formulae

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A Bethe-Weizsacker mass formula has traditionally been used to approximate the liquid-drop energy of a spherical nucleus. Using liquid-drop model mass formulae from Hirsch et al. [1], Dieperink et al. [2], Wang et al. [3], and Royer et al. [4], we compared the fits obtained with the Minuit routine of CERN's ROOT with commercial data-fitting programs Excel and Curve Expert and the data-fitting website Zunzun. We used the mass data from the 2003 Atomic Mass Evaluation [5]. Excel, Curve Expert and the Zunzun data-fitting website arrived at fitting parameter values identical to the Minuit routine of ROOT.

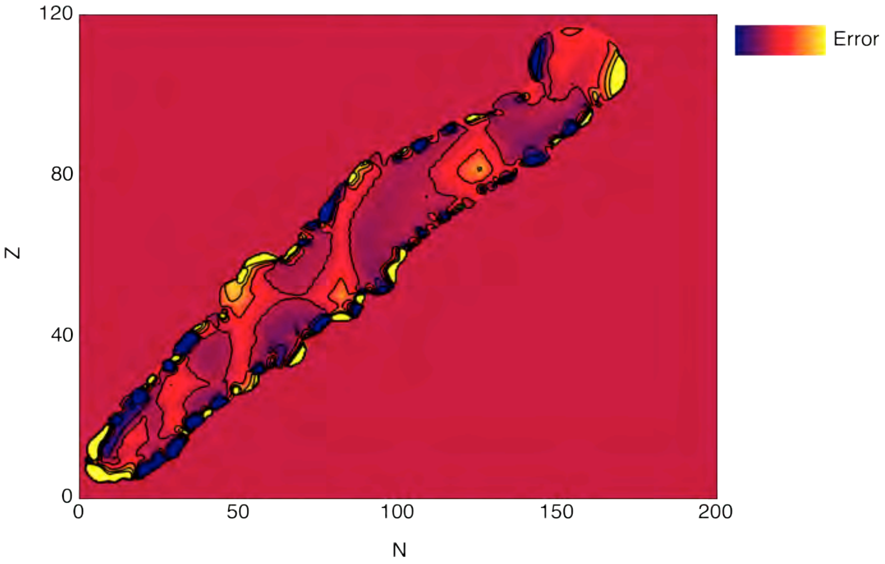

Figure 1: *Absolute Errors of a fit of LDM1 from Hirsch et al. [1] calculated with the Solver Add-in of Excel.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Discovery of microsecond isomers in neutron-rich rare-earth region by in-flight fission of 345 MeV/nucleon ^{238}U

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Neutron-rich rare-earth nuclei have attracted much attention due to the special location in the nuclear chart. They are located around the double mid-shell region of the wide open shells characterized by the conventional magic numbers, i.e., Z=50, 82 and N=82, 126. The centered region at $Z \sim 66$ and $N \sim 104$ is expected to give rise to particularly large deformation. This is predicted from the largest value of the valence nucleon product $N_{\mathrm{p}}N_{\mathrm{n}}$ that was introduced by Casten [1]. However, the lack of experimental information prevents us to address the simple but interesting question which nucleus exhibits the largest deformation as ground state in this region? This stems from the experimental difficulties in production and identification of neutron-rich rare-earth isotopes. Conventionally, the study of such isotopes was performed by using the ISOL system with particle-induced uranium fission, spontaneous fission of ^{252}Cf and multi-nucleon transfer reactions. However, the chemical properties of rare-earth elements prevent their selective extraction from a thick target, making it difficult to study more neutron-rich isotopes. On the other hand, the recent technique using a fragment separator with in-flight fission of a high-energy uranium beam is known to be powerful for producing very neutron-rich rare-earth isotopes [2]. Moreover, the fast physical process of this technique allows extremely-sensitive detection of microsecond isomers which can be populated by in-flight fission, as demonstrated by our recent work in the neutron-rich region of Z=30-50 [3].

To investigate for the first time the excited states of neutron-rich rare-earth nuclei, we performed a search for new isomers as well as new isotopes with $Z \sim 56$-68 by in-flight fission of a ^{238}U beam at 345 MeV/nucleon in the RIKEN RI Beam Factory. Fission fragments were separated and analyzed by the in-fligth separator BigRIPS. The delayed γ-rays were detected by four clover-type HPGe detectors after ion implantion at the focal plane. As a result, we discovered 19 new isomers of microsecond half-lives along with over ten new isotopes. The isomers observed are mainly located at $N \sim 100$-104 including ^{170m}Dy, providing for the first time systematic spectroscopic information in this region. We will report the experimental results on this isomer search and discuss the evolution of nuclear shape around the double mid-shell region which has never been explored until this work.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Study of the structure of light nuclei far from the stability

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The results of the recent experiments at the ACCULINNA separator of FLNR, JINR [1] and as well as the Optical Time projection Chamber (OTPC) are presented. The projectile fragmentation of light nuclei at intermediate energies (E/A = 30 ÷ 50 AMeV) have been used as a tool to produce of ^{6,8}He, ^{6}Be,^{17}Ne and ^{26,27}S. The excited states of ^{8,10}He were studied in the ^{3}H(^{6}He,p)^{10}He and ^{3}H(^{8}He,p)^{10}He reactions, respectively. The 0+ ground state of the ^{10}He nucleus was found at about 2.1 MeV. In the charge-exchange p(^{6}Li,^{6}Be)n reaction the energy spectrum of ^{6}Be was populated. The invariant mass spectrum of ^{6}Be is presented. The particle stability of ^{26}S was studied in fragmentation of ^{32}S beam at 50.3 A MeV. No events of particle-stable ^{26}S or ^{25}P were observed. The upper half-life limit of ^{26}S was established as $T_{1/2} < 79$ ns. A novel detection technique, so-called Optical Time projection Chamber (OTPC) [2,3] have been used to study exotic decay modes of ^{6,8}He,^{27}S, ^{31}Ar and ^{48}Ni isotopes. The OTPC combines techniques of a modern type of an ionization chamber with a digital photography. It allows performing event-by-event analysis of the decay cases recorded by a very sensitive CCD camera. The preliminary results of last experiments are presented.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

g-factor measurement of 7^- isomeric state in ^{128}Ba

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The transitional nuclei in the A~130 mass region have been extensively investigated, theoretically & experimentally for the γ-softness, triaxiality and shape coexistence etc. The coexistence of different shapes is expected because of the opposite shape-driving forces of protons and neutrons occupying the intruder $h_{11/2}$ orbitals [1,2]. ^{128}Ba is known to be the γ- softest nucleus in this region. The g-factor measurements give insight into the single particle nature of the state. The 7^- isomeric state in ^{128}Ba have been excited through the ^{120}Sn(^{12}C,xnγ)^{128}Ba nuclear reaction. The lifetime of the isomeric state is well suited to employ the time-differential perturbed angular distribution technique to extract the g-factor of the isomeric state. The state is known to be the neutron state and expected to have very small value of g-factor but the extracted value, $g(7^-) = +0.19 \pm 0.01$, is at variance with the systematics and the configuration assignment by the in-beam γ - ray spectroscopy[3]. The most probable configuration of the 7^- state will be presented.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Search for alpha condensed states in ^{24}Mg

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Alpha particle clustering is an important concept in nuclear physics. The most famous α cluster state is the 0_2^+ state in ^{12}C which locates at an excitation energy higher than the 3α-decay threshold by 0.39 MeV. This 0_2^+ state is theoretically described by introducing a novel concept of the nuclear structure, *i.e.*, this state has a dilute-gas-like structure where three α clusters are weakly interacting and are condensed into the lowest s-orbit [1]. The next natural question addressed is whether such α condensed states exist in heavier self-conjugate $4n$ nuclei.

Such α condensed states are theoretically predicted up to $n = 10$ [2]. The energy of the $n\alpha$ condensed state from the $n\alpha$-decay threshold increases with n due to the short-range nature of the attractive force between α clusters and the long-rage nature of the Coulomb repulsion, and the $n\alpha$ condensed state becomes unstable beyond $n = 10$.

A recent theoretical work proposed a new conformation of the α condensed state where α clusters are condensed into the lowest s-orbit around a core nucleus [3]. Attractive potential for α clusters provided by the core nucleus stabilizes the α condensed state around the core nucleus even in heavier nuclei. Thus, such α condensed states around core nuclei are expected to appear at lower excitation energies than the corresponding cluster-decay threshold energies.

Very recently, we performed a high-resolution measurement of α inelastic scattering from ^{24}Mg to search for the α condensed states with the configuration of 6α or $2\alpha+^{16}$O. The α inelastic scattering had been demonstrated as a useful probe to search for α cluster states in the previous work [4]. We also measured decaying particles from the excited states in coincidence with the inelastically scattered α particles to clarify the α cluster structure in ^{24}Mg. It is naturally expected that α cluster states should prefer to decaying into α emission channels while single-particle states should prefer to decaying into proton or neutron decay channels. We compared the excitation energy spectra in ^{24}Mg decaying into ^{20}Ne and ^{16}O through the α and ^{8}Be emission with that decaying into ^{23}Na through the proton emission, and found several possible candidates for the α-condensed states in ^{24}Mg.

In the present talk, we will present the experimental details and preliminary results on the α condensed states in ^{24}Mg.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Coulomb excitation of ^{196,198,200,202}Po studied at REX-ISOLDE with the Miniball γ spectrometer

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The neutron-deficient polonium isotopes with two protons outside the closed Z = 82 shell represent an interesting region of the nuclear chart to study shape coexistence in nuclei. ^{200}Po manifests itself as a transitional nucleus between a general-seniority-type regime in the heaviest polonium isotopes and a shape-coexistence character in the lightest polonium isotopes [1,2]. However, questions remain concerning this transition; the sign of deformation and the magnitude of mixing between the different configurations are still unclear. Coulomb excitation at safe energies serves as a vigorous technique to investigate the magnitude of transitions between low-lying states, revealing information on the deformation of these states and on the mixing of the different bands.

In the September 2009 test phase of the experimental campaign [3] ^{200}Po beams were produced and post accelerated to an energy of 2.85 MeV/u at the REX-ISOLDE facility in CERN. The radioactive ion beam was delivered to a stable ^{104}Pd target placed in the middle of the Miniball γ spectrometer to induce Coulomb excitation. There was little or no contamination with a beam purity of 98.8(9)% and the count rate of $\sim10^6$ pps at Miniball with a proton beam intensity of 1.1μA confirmed the predicted count rates.

The test phase was followed by a successful continuation of the experimental campaign in September 2012. During the remaining beam time, beams of ^{196,198,202}Po were produced and post accelerated at REX-ISOLDE and Coulomb excitation was observed at the Miniball detection setup for all the isotopes. Furthermore parasitic data on the Coulomb excitation of ^{196}Tl, which was the 50% contaminant in the ^{196}Po beam, was gathered.

Using the Coulomb excitation analysis code Gosia [4] and the experimental information it will be possible to determine the B(E2) values coupling the low-lying excited states for the whole transitional range ($^{196\text{-}202}$Po). In ^{196}Po it will be especially interesting to compare the B(E2) value from the Coulomb excitation experiment to the value determined from the lifetime experiment [5]. The amount of statistics will also allow us to fix the sign of the quadrupole moments of the first excited 2^+ states. Finally these results will be discussed within the framework of shape coexistence and mixing. They will also be compared with recent results from beyond mean-field calculations [6]. In the presentation the first results from the 2012 experimental campaign will be shown together with the results from 2009.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Neutron skin thickness in the Skyrme EDF models

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Thanks to the new radioactive beam facilities, the experimentally known region of the nuclear landscape will be pushed towards more and more exotic nuclei. New experimental data on nuclei with large proton or neutron excess will undoubtedly put current theoretical models to the test. Therefore, it is crucial to quantify predictive power of the models used to describe atomic nucleus. Some of the interesting quantities, to test the models and their uncertainties, are the predicted limits of the nuclear landscape [1] and predictions related to the neutron skin thickness [2].

To cover the entire nuclear landscape, the microscopic tool of the choice is the nuclear density functional theory (DFT). In nuclear DFT, the effective interaction is parameterized by the energy density functional (EDF). Because EDF parameters have to be optimized to the empirical input, they also contain certain uncertainties. These uncertainties propagate to the observables calculated within the model.

A method to assess the predictive power of the DFT models is to calculate either the systematic or statistic error of some observable, predicted by the model. With well-calibrated Skyrme-EDFs we found neutron drip-line to be rather well defined [1]. As expected, the systematic deviation in two-neutron drip-line increases towards heavier nuclei. This is linked to the isovector part of the EDF, which is not so well constrained as the isoscalar one. The situation is similar with the statistical error.

With the neutron skin thickness, both, the systematic and statistical error increase towards neutron drip line [2]. This is shown in Fig. 1a, where neutron skin thickness and statistical model error for Zr isotopic chain has been plotted. Again, this behavior is directly linked to the larger theoretical uncertainties related to the isovector part of the Skyrme-EDFs. The major contributor to the statistical error here is the density dependent part of the symmetry energy. Concerning the recent PREX experiment of the neutron skin thickness in ^{208}Pb, we have found that current theoretical uncertainties are smaller compared to the experimental error bar, see Fig. 1b. This is consistent with findings of Ref. [3].

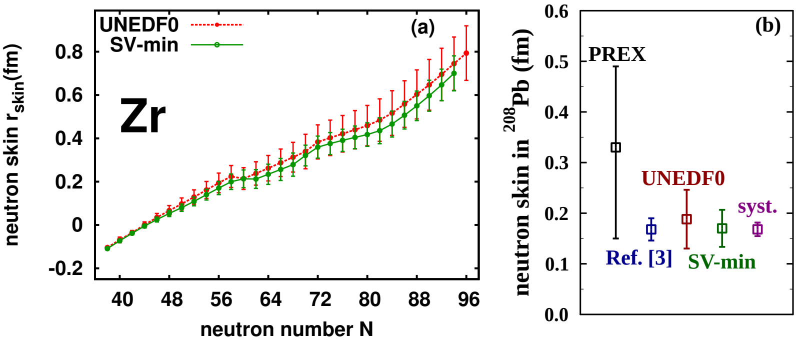

Figure 1: *(a) Predicted neutron skin thickness and statistical model error in Zr isotopes, and (b) in ^{208}Pb together with experimental PREX result and systematic model error of Ref. [3] and this work.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Mass measurements at ISOLDE

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The ISOLDE/CERN mass measurement programme is presently carried out with the ISOLTRAP setup [1], which has provided high-precision masses of almost 600 atomic nuclei [2] with production yields down to a few 10 ions/s and half-lives below 100 ms. The obtained binding energies are relevant to the nuclear structure studies, nuclear astrophysics, or studies of fundamental interactions. Since the last INPC conference numerous nuclei have been investigated with ISOLTRAP, some of which could be addressed only thanks to technical upgrades, both on the ISOLDE and ISOLTRAP [3] sides.

The recent mass measurements at ISOLTRAP cover the whole nuclear chart. In the light-mass region calcium isotopes have been investigated up to ^{54}Ca [4], relevant for the nuclear-structure studies, especially in the context of three-body forces. In the medium-mass range the long-sought mass of ^{82}Zn has been determined [5], which is important for the N=50 shell closure and for astrophysics studies, e.g. in determining the structure of neutron stars. Above Z=50, neutron-rich caesium isotopes up to ^{149}Cs have been investigated. Finally, several experimental campaigns have been devoted to Au, Tl, At, Fr, and Ra isotopes, interesting among others because of their proximity to the double shell closure at ^{208}Pb. The results include masses of very neutron-rich francium and radium isotopes, up to ^{234}Ra and ^{233}Fr, where the latter isotope has been identified for the first time.

Among the recent technical upgrades at ISOLTRAP, the major addition is an electrostatic mirror trap [6]. The device acts as a multi-reflection time-of-flight mass separator (MR-TOF MS) and has been already used to clean away isobaric contaminants (e.g. for ^{82}Zn) or even to determine atomic masses (e.g. ^{54}Ca). Because the ions spend in this trap only a dozen of ms, it has given ISOLTRAP access to shorter-lived and less produced nuclides. MR-TOF MS has also found a novel application - that of investigating the hyperfine structure of laser-ionised nuclides, used for the first time for neutron-deficient gold isotopes. On the ISOLDE side, several developments in targets and ion sources, leading to increased yields and lowered contaminants, have been crucial in the studies of, e.g. ^{82}Zn, as well Ca and At isotopes.

This contribution will give a short introduction to the measurement method and experimental setup, followed by an overview of several of the above scientific and technical achievements.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Establishing the neutron magic number $N = 32$ with mass measurements of ^{53,54}Ca using ISOLTRAP's MR-TOF MS

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To understand the different components of the nuclear force, the investigation of structural effects towards the outskirts of the nuclear chart - like shell-quenching or the emergence of new magic numbers - are of utmost importance. The calcium isotopic chain with a closed proton shell and two doubly-magic nuclei is an ideal test-bench for nuclear shell evolution. It has been extensively studied experimentally as well as theoretically from the valley of stability to the verge of existence. The new mass values of ^{53,54}Ca reported here provide strong evidence for a shell closure at $N = 32$. Moreover, the new masses offer a stringent test for microscopic calculations with three-nucleon forces derived from state-of-the-art chiral effective-field theory.

Precision measurements on radioactive ions are performed with the mass spectrometer ISOLTRAP at CERN. Minute production rates, which are often mixed with huge amounts of isobaric contamination, and millisecond half-lives pose enormous challenges on the experimental setup and often require new experimental techniques. For the measurements discussed in this contribution, the recently installed multi-reflection time-of-flight mass separator (MR-TOF MS) has been used as a spectrometer. The measurements of the calcium isotopes will be presented together with an overview of the enhanced ISOLTRAP setup. It will be discussed how the masses of exotic calcium isotopes pin down nuclear forces.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Coulomb excitation of exotic nuclei at REX-ISOLDE with MINIBALL

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We present in this contribution results obtained at the REX-ISOLDE facility at CERN which now operates successfully for more than 10 years. So far, post-accelerated beams of more than 80 isotopes of elements ranging from Li to Ra have been produced and delivered to experiments. Currently, beam energies up to 3 MeV/u are available.

Most important instrument for the study of exotic nuclei at REX-ISOLDE is the highly efficient MINIBALL spectrometer consisting of 8 triple clusters of six-fold segmented HPGe detectors. The γ-rays are usually measured in coincidence with beam- and target-like nuclei detected by several set-ups of segmented Si detectors.

Many experiments employ "safe" Coulomb excitation as a tool to study collective properties of exotic nuclei through the determination of electromagnetic matrix elements. Other observables, like lifetimes or g factors, are measured by dedicated methods.

One corner stone of the physics programme aims for the study of the evolution of collectivity, in particular near shell closures. Key nuclei and questions investigated at REX-ISOLDE by Coulomb excitation are

- ^{30,32}Mg at the shore of the "island of inversion";
- neutron-rich Cu isotopes, ^{68}Ni, and $^{74-80}$Zn in the region around $Z = 28$ and $N = 40, 50$;
- the onset of deformation around $N = 60$ in ^{94,96}Kr;
- the region around ^{132}Sn including neutron-rich Cd, Xe and Ba isotopes;
- the lack of shell stabilization in the $N = 80$ isotones ^{140}Nd and ^{142}Sm;
- the phenomenon of shape coexistence in light Hg and Po isotopes;
- octupole collectivity in Rn and Ra isotopes, in particular the first measurement of the octupole strength in ^{224}Ra.

The step-wise upgrade of REX-ISOLDE to HIE-ISOLDE has been started already. It aims for a higher beam energy of up to 10 MeV/u, higher beam intensities, and improved beam quality. In parallel, also the instrumentation will be upgraded. These developments will extend the physics programme conducted at ISOLDE to new horizons.

We will present the status of the facility and the research programme as well as discuss the perspectives for future experiments.

This work is supported by the German BMBF under grants No. 06DA9036I and 05P12RDCIA, HIC for FAIR, EU through EURONS (No. 506065) and ENSAR (No. 262010) and the MINIBALL and REX-ISOLDE collaborations.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Investigation of low-energy dipole modes in the heavy deformed nucleus ^{154}Sm via inelastic polarized proton scattering at zero degree

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Polarized proton scattering has been measured on the heavy deformed nucleus ^{154}Sm at extreme forward angles with 300 MeV protons at RCNP, Osaka. The aim is to investigate the impact of ground state deformation on the properties of the electric pygmy dipole resonance (PDR) and the spin $M1$ resonance previously claimed to show a double-hump structure in heavy deformed nuclei. The (p,p) cross sections can be decomposed into $E1$ and $M1$ parts in two independent ways based either on a multipole decomposition of the cross sections or on spin transfer observables [1]. The analysis of polarization transfer observables shows dominant non-spinflip cross sections in the excitation energy region 5-9 MeV with a resonance structure interpreted as the PDR, while the spinflip $M1$ strength shows a broad distribution between 5 and 10 MeV. We also present first data of a multipole decomposition analysis.

* This work is supported by the DFG through SFB 634 and NE679/3-1.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Overview of the Search for New Isotopes and New Isomers at RIKEN RI Beam Factory

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A new-generation rare-isotope (RI) beam facility called the RI Beam Factory (RIBF) [1] became operational in 2007 at RIKEN Nishina Center, aiming to greatly expand the frontiers of accessible exotic nuclei. The BigRIPS in-flight separator [2,3,4] has been used to produce a variety of RI beams at RIBF, being characterized by its large acceptances and two-stage structure. The large acceptances allow efficient RI-beam production using in-flight fission of a ^{238}U beam, in which fission fragments are produced with large angular and momentum spreads. The two-stage structure allows not only two-stage separation but also excellent particle identification of the fragments. The BigRIPS separator is designed so as to exploit the advantageous features of in-flight fission, which is known to be an excellent mechanism for producing a wide range of neutron-rich exotic nuclei.

Since the commissioning of the RIBF, we have three times performed search for new isotopes using in-flight fission of 345 MeV/nucleon ^{238}U, in order to expand the regions of accessible exotic nuclei. In the first run in May 2007 [5], we easily reached the frontiers of known isotopes and observed the new neutron-rich isotopes ^{125}Pd and ^{126}Pd, although the beam intensity was as low as 0.007 pnA on average and the net running time was only one day. The discovery of these Pd isotopes demonstrated not only the performance of the BigRIPS separator, but also the potential of RIBF.

In November 2008 we revisited the search with ~30 times higher beam intensity than in 2007. The results demonstrated the overwhelming RI-beam production power at RIBF. [6] We ran the measurement at three different settings, each of which targeted the production of new neutron-rich isotopes in the $Z \sim 30$, $Z \sim 40$, and $Z \sim 50$ regions, respectively. The net running time was only four days and the average beam intensity was 0.22 pnA. We were able to identify 45 new isotopes over a wide range of very neutron-rich nuclei with Z numbers ranging from 25 to 56. For Pd isotopes, we observed the more neutron-rich isotopes ^{127}Pd and ^{128}Pd, reaching the r-process waiting point at the $N = 82$ neutron magic number. While searching for new isotopes, delayed γ-rays emitted from microsecond isomers were simultaneously detected at the focal plane after ion implantation. We observed a total of 54 isomers, including 18 new isomers in very neutron-rich exotic nuclei, and obtained a wealth of spectroscopic information, allowing investigation of nuclear isomerism and nuclear structure over a wide range of neutron-rich exotic nuclei [7].

In October 2011, we ran the search for new isotopes and new isomers in the neutron-rich frontiers with $Z \sim 60$. The ^{238}U beam intensity was about 0.2–0.5 pnA. Our preliminary results indicate the observation of a number of new isotopes and new isomers in this neutron-rich region.

An overview of the search for new isotopes and new isomers at RIBF will be presented.

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β decay $^{231}\mathrm{Th} \rightarrow {}^{231}\mathrm{Pa}$

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The energies, spectroscopic factors, magnetic dipole and electric quadrupole moments of the ground and excited states of ^{231}Pa, as well as reduced probabilities of the electromagnetic transitions between them and the reduced probabilities of β transitions from the ground state of ^{231}Th to the excited states of ^{231}Pa have been calculated in the framework of dynamic collective model [1]. The method from [2] has been used for the calculation of β^- decay $^{231}\mathrm{Th} \rightarrow {}^{231}\mathrm{Pa}$. Multi-phonon states (up to ten phonons) of main band of even-even core and the influence of vacuum fluctuations of quasiparticles on the renormalization of one-particle moments and effective forces are taken into account.

β^- decay occurs because the neutron chemical potential lies above the proton one. The difference between chemical potentials correlates with energy of β decay Q = 389 keV.

β^- decay goes from the ground state $5/2_1^+$ of ^{231}Th in which the contribution give almost all neutron subshells with the even orbital moments from filled shell. The β transitions occur with maximum intensity and probability to $5/2_1^+$ and $7/2_1^+$ states of ^{231}Pa, formed by bonding of one-quasiparticle state $13/2_1^+$ with phonon states of even-even core with full moments R = 4, 6, 8, 10. The comparison of experimental [3] and calculated lg *ft* are present in the table.

I^π	$5/2_1^+$	$7/2_1^+$	$3/2_1^+$	$5/2_2^+$
E_{exp}, keV	84.2	101.4	102.3	183.5
I, %	35	37	12	12.8
lg *ft*, exp.	6.0	5.9	6.4	5.9
lg *ft*, cal.	6.2	5.8	6.4	6.2

The renormalization of the constants of weak interaction in this calculation was the same as for the nuclei with A $\approx$ 100.

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About the renormalization of weak interaction constants in nuclei

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The beta-transitions to the ground and excited states of nuclei usually were considered as one-particle in various models, including the deformed atomic nucleus [1], nonaxial deformed nucleus [2], one-particle and many-particle shell models [3, 4]. Only the contributions of one-phonon configurations to the wave functions were taken into account in quasiparticle-phonon [5] and microscopic quasiparticle-phonon models [6]. The probabilities of intensive beta-transitions for some nuclei calculated in this models differed from the experimental one about two orders of magnitude.

On the basis of dynamic collective model (DCM) we have elaborated the method for calculation of the reduced probabilities of beta transitions to the excited states of odd nuclei with the account of quasiparticle and multi-phonon (up to 10 phonons) states, Pauli's principle and vacuum fluctuations between collective and onequasiparticle freedom degrees [7]. Renormalization of weak interaction constants for nuclei from area A = 100, defined in work [7] from systematization of experimental data, has been taken as a base of studying of the role of structural effects on β decay of odd nuclei:

$$\left[\frac{g_A}{g_V}\right] = 0.343\left[\frac{g_A}{g_V}\right]_{free} .$$

About 30 years it was supposed that renormalization of weak interaction constants in nuclei is caused by influence of Fermi and Gamow-Teller resonances, therefore can be different for various nuclei due to strong difference of Fermi surfaces in them.

The calculations carried out in DCM for nuclei with 31 <A < 231 have shown, that in cases of satisfactory description of spectrum and spectroscopic characteristics of daughter nuclei a good description of nuclei β decay with the same renormalization of weak interaction constants turns out. The calculated probabilities with intensity > 10% differed from experimental one by 0,02 - 0,4 order of magnitude. Modern experimental data on the $^{111}\mathrm{Sb} \rightarrow {}^{111}\mathrm{Sn}$ β decay, received by means of the detector of full absorption, differ from older one. Therefore divergences of results of calculations with experiment in some nuclei can be caused inaccurate experimental data.

Hence, the renormalization of weak interaction constants does not depend of Fermi surface of nuclei, so and from Fermi and Gamow-Teller resonances. This fact leads us to the conclusion that the reason of renormalization of weak interaction constants in nuclei is necessary to search in non nucleon degrees of freedom which, probably, are opened since some value of mass number and further do not depend on it.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Nuclear Vorticity in Giant Resonances: Skyrme RPA Analysis

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As recently shown, the multipole vortical, toroidal, and compression modes can be analyzed on the same theoretical footing as second-order corrections to the familiar multipole electric transition operator [1]. The method follows the vorticity concept of Ravenhall and Wambach [2] and allows to establish a simple relation between the multipole vortical operator and the toroidal/compression ones. The method is implemented to the Skyrme self-consistent separable random-phase approximation (SRPA) approach known as an effective and reliable theoretical tool for investigation of electric [3] and magnetic [4] giant resonances.

First calculation for E1 vortical, toroidal, and compression strengths in 208Pb have shown that the vortical and toroidal modes are dominated by the convection nuclear current in the isoscalar (T=0) channel and by magnetization nuclear current in the isovector (T=1) channel. The compression mode is fully convective in both channels.

In the present study, we continue exploration of the nuclear vorticity and related toroidal and compression modes. The difference between the Wambach's [2] and hydrodynamical prescriptions of the vorticity is scrutinized. Dependence of the results on Skyrme parameterizations and characteristics of nuclear matter is explored. Possible ways of experimental observation of the modes are discussed. Both spherical and deformed nuclei from different mass regions are covered. Effect of the nuclear deformation is analyzed.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Precision measurement of the Electromagnetic dipole strengths in ^{11}Be

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Light nuclei near the neutron drip line are of interest theoretically and experimentally since they exhibit unique features not observed elsewhere. The one-neutron halo nucleus ^{11}Be has the fastest known $E1$ transition between bounds states and the strength to the continuum exhausts 70% of the cluster sum-rule [1]. Accuracies for the $B(E1)$ values of $\sim$10% between the two bound states [2,3] and $\sim$5% to the continuum of ^{11}Be [1] have been reported, but with a $\sim$15% discrepancy between the strengths for the latter. In the current work, the $E1$ strengths to the 320 keV state and to the continuum from the ground state of ^{11}Be were investigated with Coulomb excitation on a ^{196}Pt target at $E(^{11}\mathrm{Be})$=1.73, 2.09, and 3.82 MeV/A using the TIGRESS/Bambino array at TRIUMF. Only the two lowest energies were used to determine the $B(E1)$'s from the yields of the 320 keV transition relative to the 2^+ to 0^+ in ^{196}Pt, see Fig. 1. The analysis was carried out using a semi-classical reaction code, Gosia [4], and a quantum mechanical reaction code, the extended continuum discretized coupled channels model (XCDCC) [3]. The strength between bound states in ^{11}Be was deduced using Gosia and XCDCC relative to the ^{196}Pt yields which were calculated using the adopted value for the $B(2^+\!\rightarrow\!0^+)$ of 0.274(1) e^2b^2. The latter includes an extended wave function for ^{11}Be from a deformed core+coupled-channels particle cluster model [5] and is also used to determine the $E1$ strength to the continuum. The $B(E1)$ value of 0.102(2) e^2fm^2 deduced from our analysis between the bound states is $\sim$12% and two sigma lower than the lifetime measurement, but in agreement with the results from intermediate energy Coulomb excitation. The higher accuracy achieved in the present work will not only help resolve the discrepancies of the previous works, but also help isolate the importance of contributions from individual terms of the NN interactions in models that describe halo systems such as the No-Core Shell Model plus Resonating Group Method [6]. The experimental details, our results and its implications will be presented.

This work is performed in part under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

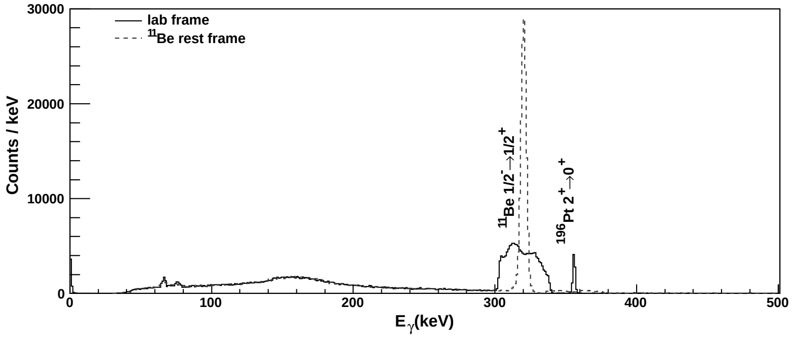

Figure 1: *The background subtracted particle γ coincidence spectra at $E(^{11}Be)$ = 2.09 MeV/A.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Isospin Symmetry Violation in sd Shell Nuclei

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The effect of isospin nonconservation is crucial for testing the fundamental symmetries underlying the Standard Model, e.g., corrections to superallowed $0^+ \rightarrow 0^+$ β-decay rates [1], and is pivotal for computing theoretical amplitudes for nucleon transfer reaction which violates isospin selection rule [2]. However, getting an accurate theoretical description of the isospin-symmetry violation within a microscopic model is a great challenge. Existing calculations within various approaches do not agree on the magnitude of isospin impurities and predict very different values for the corrections to nuclear β decay.

Recently, we have constructed a realistic isospin-nonconserving (INC) shell-model Hamiltonian in sd-shell. It includes a well-established isospin-conserving Hamiltonian, e.g. USD, USDA or USDB interactions [3], a two-body Coulomb interaction and a phenomenological charge-dependent part describing the isospin-symmetry breaking part of the effective nucleon-nucleon interaction. The charge-dependent strengths were determined by a least-squares fit to reproduce newly compiled experimental coefficients of the isobaric multiplet mass equation (IMME) [4] with very low root-mean-square deviation values ~33 keV [5]. This INC Hamiltonian provides an accurate theoretical description of the isospin mixing in nuclear states.

In this contribution, we discuss a few important applications:

- We propose the first microscopic description of the staggering behavior of isovector and isotensor IMME coefficients showing the excellent agreement between the shell model and the experiment. Contributions to this mechanism from the Coulomb interaction and effective charge-dependent forces of nuclear origin are shown.

- We explore the breaking of the quadratic IMME in $A = 24, 28, 32$ quintets. Comparison of our results with recent high-precision experimental data and theoretical analysis [6] is presented. Our theoretical isovector coefficients are just ~10 keV deviate from experimental values. We also deduce coefficients of the possible high-order terms in T_z in the IMME.

- We present calculations of isospin-forbidden proton emission branching ratios. Our results on ^{22}Al decay resembles more experimental spectra [7] than the earlier calculations [8].

- Finally, we calculate a new set of isospin-mixing corrections to superallowed $0^+ \rightarrow 0^+$ β-decay rates in comparison with the latest results of Towner and Hardy [1].

Overall, this new INC Hamiltonian shows its robustness in describing isospin-symmetry violation effects in sd shell nuclei.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Spectroscopy of the drip-line ^{6,7,8}He nuclei via direct reactions on proton

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The nuclear models disagree for the predictions of the spectroscopy of nuclei far away from the valley of stability, due to their different assumptions on nucleon-nucleon interactions and on the few-body correlations at play. New interesting phenomena, related to the weak binding energies, are observed close to the neutron drip-line, such as halos or neutron skins, and low-lying resonant states. The existence and position of these states in the light exotic nuclei, challenging the nuclear theories, could provide crucial information to check the microscopic inputs of the newly improved structure models and to test the validity of their assumptions.

Recently we have investigated the low-lying spectroscopy of the weakly-bound halo ^{6}He, of the unbound ^{7}He and of neutron-skin ^{8}He nuclei, in order to compare the excitation energies with the theoretical predictions. The excited states of ^{7}He and ^{6}He were explored by measuring the one (p,d) and two-neutron (p,t) transfer reactions of ^{8}He beam on a $(CH_2)_n$ proton-rich target, respectively. We carried out the experiment at GANIL using the ^{8}He SPIRAL beam at 15.4*A*.MeV and the large angular coverage telescope MUST2 array [1] a specific tool for the detection of the light charged particles produced in the direct reactions. The ^{6,7}He excitation spectra were deduced via missing mass method, from the kinematical characteristics of the particles measured in MUST2.

We have obtained new resonant states of ^{6}He [2]. Above the known 2^+ state, two new resonances were observed: at E* = 2.6 (3) MeV [width Γ= 1.6 (4) MeV], and at 5.3(3) MeV with Γ=2(1) MeV. Through the analysis of the angular distributions, they correspond to a 2^+ state and to an L=1 state, respectively. Moreover, the new extended ^{8}He(p,t) angular distributions provide a complete data set to discuss the neutron configurations of ^{8}He with respect to the ^{7}He and ^{6}He ones, in the framework of the coupled-reaction-channel (CRC) calculations, which was already shown to represent a powerful method to describe consistently a whole set of reaction data for ^{8}He [3, 4]. In this talk, we propose to present our experimental study of the low-lying excited states of ^{6}He, ^{7}He and to compare them to the predictions obtained recently by various theoretical frameworks, like, for instance, the ab-initio calculations [5], the no-core shell model [6], and the models including an explicit treatment of the continuum couplings of bound and scattering states [7,8,9].

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Description of light nuclei ($10 \leqslant Z, N \leqslant 18$) with the multiparticle-multihole Gogny energy density functional

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In my talk, I will present some spectroscopic properties for a few sd-shell even-even nuclei [1]. The results have been obtained in the framework of the multiparticle-multihole configuration mixing approach (mp-mh) [2, 3] wich consists of a unified variational treatment of nuclear long-range correlations. The same effective nucleon-nucleon interaction, namely the D1S Gogny effective force, is used in both the mean-field and the residual channels.

Excitation energies, magnetic and quadrupole moments as well as B(E2) and B(M1) calculations are performed for sd-shell even-even nuclei with $10 \leqslant Z \leqslant 18$ and $10 \leqslant N \leqslant 18$. Low-lying positive-parity states are considered. The results are compared with those of a standard GCM-type method [4] using the same Gogny D1S interaction and also with experimental data. A very good agreement compared to experiment is obtained for the energies, magnetic moments and B(M1) transition probabilities. The sign as well as the order of magnitude is globally obtained for quadrupole moments. Finally, along isotopic and isotonic chains the experimental trend is generally reproduced for the B(E2) transitions probabilities.

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Do light nuclei exhibit “collective“ motions?

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The Lorentz integral transform (LIT) method has allowed to perform ab initio calculations of the response function of ^{4,6}He, and ^{6,7}Li to the isoscalar monopole [1] and isovector dipole operators [2,3] in a wide range of energies. In this work we focus in particular on the nature of the resonant behaviour of the cross sections exhibited by the results of those calculations and specialize in the ^{4}He case, where one has a 0^{+} resonance close to the 3+1 thresholds. In fact, in inelastic electron scattering off ^{4}He one finds a pronounced resonant structure in the isoscalar monopole strength. The knowledge of this strength as a function of energy makes possible calculations of the corresponding non-energy weighted as well as energy-weighted and inverse energy-weighted sum rules. Comparing the sum rules with their contribution from the resonance region allows to establish the degree of collectivity of the resonant structure.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Nuclear Structure of neutron-rich nuclei around N=40

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Far from the valley of beta stability, the nuclear shell structure undergoes important and substantial modifications. In medium-light nuclei, interesting changes have been observed such as the appearance of new magic numbers, and the development of new regions of deformation around nucleon numbers that are magic near stability. The observed changes help to shed light on specific terms of the effective nucleon-nucleon interaction and to improve our knowledge of the nuclear structure evolution towards the drip lines.

In the last few years, particular effort has been put on studying light and medium-mass neutron-rich nuclei where these effects manifest more dramatically. Detailed nuclear structure information is becoming available both with stable and radioactive beams in Cr, Mn, Fe and Co isotopes in the mass region around N=40, where rapid changes of the nuclear shape occur along isotopic and isotonic chains.

A review of the recent experimental findings in this mass region will be presented together with their interpretation in terms of the interacting shell model in a wide valence space.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Spectroscopy of ^{26}F to probe proton-neutron forces close to the drip line

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Nuclear forces play a decisive role to account for the creation and modifications of shell gaps, to explain deformed nuclei, to permit the development of halo structures and to fix the limits of particle stability. The study of neutron-rich nuclei is particularly important to determine the limits of 'stability' and to reveal the disappearance or emergence of new shell gaps far from stability.

The neutron-rich ^{26}F is a benchmark nucleus for studying proton-neutron interaction close to drip line. First, its binding energy amounts to only 0.80(12) MeV. Second, it lies close to the ^{24}O doubly magic nucleus. Therefore its nuclear structure at low excitation energy is expected to be rather simple: it is mainly provided by the interaction between a deeply proton $d_{5/2}$ (~ -15.1 (3) MeV) and an unbound neutron $d_{3/2}$ (~ +0.77 (20) MeV) on top of a closed ^{24}O core, leading to $J = 1, 2, 3, 4$ positive parity states. The search for these states has been investigated at GANIL and GSI using three experimental techniques. The J = 2 state has been determined by in-beam γ-ray spectroscopy technique using fragmentation reactions of a cocktail of radioactive nuclei at GANIL. The J = 4 state, expected to be isomer, has been discovered at GANIL as well by the study of the ^{26}F ground and isomeric β-decay to ^{27}Ne. Finally, a proton knockout experiment on ^{27}Ne (currently under analysis) made at GSI using the neutron detector LAND, should allow us to determine the energy of the 3^+ state. Combining these pieces of information with those obtained from atomic mass measurement, we determine the experimental states $J = 1^+ - 4^+$ arising from the $\pi d_{5/2} - \upsilon d_{3/2}$ coupling in ^{26}F. We then compared these results to calculations obtained from two theoretical approaches, the nuclear shell model and the Coupled Cluster theory, to test the nuclear forces far from stability, where a large proton-to-neutron binding energy asymmetry is present. We found that these states are more compressed than in USDA and USDB shell model results, and the $J = 1^+$, 2^+ and 4^+ states are less bound as well. These two effects point to a dependence of the effective two-body interaction used in the shell model as a function of the proton-to-neutron binding energy asymmetry. Coupled-cluster calculations including three-body forces and coupling to the particle continuum are in excellent agreement with experiment for the bound low-lying states in ^{26}F (see figure below). Calculations for unbound states are currently under development. These results were accepted for publication in PRL.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Lifetime Measurements in ^{160}Gd

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The nature of low-lying excitations, $K^{\pi} = 0^{+}$ bands in deformed nuclei remain enigmatic in the field, especially in relationship to quadrupole vibrations. One method of characterizing these states is by reduced transition probabilities, B(E2) values, a measure of the collectivity. These values can be measured directly by Coulomb excitation or calculated from measured lifetime values. Within the deformed region, there are five stable Gd isotopes, three of which have been studied to obtain B(E2) values, a fourth, ^{160}Gd is the focus of this work. We have examined ^{160}Gd with the $(n,n'\gamma)$ reaction and neutron energies up to 3.0 MeV to confirm known 0^{+} states. Angular distributions at three different neutron energies were performed to determine their lifetimes through DSAM measurements. Preliminary gamma-ray excitation functions, angular distribution, and lifetime measurements will be presented.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Less-Empirical Nuclear Density Functionals from Low-Momentum Interactions

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Density functional theory is the most general quantum-mechanical method for predicting properties of medium-mass and heavy nuclei. However, progress in the experimental study of heavy and neutron-rich nuclei challenges its accuracy and predictive power. Construction of nuclear density functionals has been, up to now, mostly phenomenological, while current efforts [1] aim to supplement this by including knowledge about the nuclear many-body problem in its first-principles formulation. I will report on progress towards functionals based on a factorized [2,3] form of soft, vacuum two-body [4,5] and three-body [6] interactions that promise to make the use of the latter feasible in calculations of medium-mass and heavy systems, allowing more reliable theoretical extrapolations towards the limits of nuclear stability.

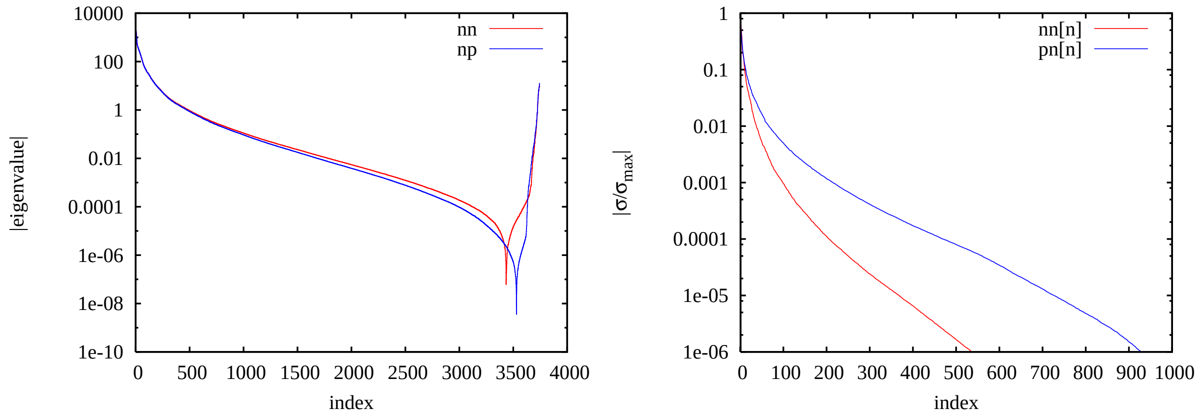

Figure 1: Left: eigenvalues of the matrix made of matrix elements of the $V_{\text{low }k}(\Lambda = 1.8\text{fm}^{-1})$ interaction, couple to $J^\pi = 0^+$ (particle-hole). Right: singular values of the 3-tensor [7] made of matrix elements of a three-body interaction deduced from chiral EFT ($\Lambda_{3\text{N}} = 2.0\ \text{fm}^{-1}$) also coupled to $J^\pi = 0^+$ in a single-partiecle basis of spherical Bessel functions.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Nuclear charge-exchange excitations in localized covariant density functional theory

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Nuclear charge-exchange excitations are crucial to understand many important topics in nuclear physics, astrophysics, and particle physics, such as nuclear spin and isospin properties, effective nucleon-nucleon tensor interactions, neutron skin thickness, nuclear β-decay rates in r-process nucleosynthesis, unitarity of Cabibbo-Kobayashi-Maskawa matrix, etc.

The fully self-consistent descriptions of charge-exchange excitations in covariant density functional theory (CDFT) were achieved only recently [1] with the RPA based on the density-dependent relativistic Hartree-Fock (RHF) theory [2]. The characteristics of isobaric analog and Gamow-Teller resonances [2,3] as well as the fine structure of spin-dipole resonances [4] can be nicely understood by the delicate balance between the σ- and ω-meson fields via the exchange terms. Nevertheless, the RHF theory includes non-local potentials, which is much more involved than the conventional CDFT in the Hartree level. Therefore, it is also desirable to stay within the Kohn-Sham scheme and to find a covariant density functional based on only local potentials, yet keeping the merits of the exchange terms.

In Ref. [5], we proposed a new kind of RHF equivalent local covariant density functional. The corresponding isovector channels, which can be barely controlled in ground-states descriptions, are constrained by the Fock term effects of the RHF scheme. It is found that the charge-exchange excitations can be naturally reproduced in such localized framework. This retains the advantages of conventional CDFT models and provides proper descriptions of nuclear isovector properties.

In order to extend this approach to the deformed systems, one of the ongoing projects is the self-consistent relativistic RPA based on the above functionals with the finite amplitude method (FAM). The FAM provides an efficient way to find the RPA equation solutions, in particular, when the dimension of the matrix is huge as in the deformed case [6]. The feasibility of the FAM for CDFT has been demonstrated [7]. Meanwhile, it is shown that the effects of Dirac sea can be taken into account implicitly in the $\mathbf{r}$-space representation and the rearrangement terms due to the density-dependent couplings can be treated practically without extra computational costs.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

The Orsay Universal Plunger System

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Detailed spectroscopic information is, together with the nuclear mass, the experimentally accessible observables used to understand the many-body nuclear problem. The energies of excited states, although fundamental, give an incomplete picture of the nuclear-state wave function and are therefore by themselves insufficient for detailed scrutinizing of nuclear structure models. An additional sensitive probe of the nuclear wave function is the electromagnetic transition strength $\mathrm{B(E/ML{:}J}_i \rightarrow \mathrm{J}_f)$. The measurement of the lifetime of an excited state gives a completely model-independent measurement of the $\mathrm{B(E/ML{:}J}_i \rightarrow \mathrm{J}_f)$, given that the transition de-exciting the state in question is not of mixed multipolarity.

In this contribution a so-called “plunger ” device will be described. The “plunger“ consists of a thin target foil for the production of recoiling exited nuclei and a “stopper” foil at a well defined distance from the target and is used with the Recoil Distance Doppler Shift (RDDS) method [1]. Using the RDDS method together with a plunger device lifetimes of about one to a few hundreds of picoseconds can be measured with a precision comparable to that of the statistical uncertainty. Such experiments therefore deliver high quality data on electromagnetic transition strengths. The distance between the target and stopper foil used for RDDS experiments is approximately given by the product of the lifetime of the excited state and the recoil velocity of the nuclei. This corresponds in many cases to less than a few tens of micrometers. A major technical challenge for a plunger device is therefore to keep the target- and stopper-foil parallel and at a fixed distance while they are heated by the beam.

Because of the sensitivity of the $\mathrm{B(E/ML{:}J}_i \rightarrow \mathrm{J}_f)$ value to the wave function, and the model independent determination of electromagnetic transition strengths given by plunger measurements, this technique will play an important role in the physics campaigns at future radioactive beam facilities, such as Spiral2 at GANIL [2]. Traditionally used together with heavy-ion fusion evaporation reactions recent developments have shown that the RDDS technique is also suited to measure lifetimes of excited states populated in multi-nucleon transfer reactions [3,4], intermediate-energy Coulomb excitation studies [5], low-energy multistep Coulomb excitation studies [6], as well as together with induced fission reactions to measure lifetimes of excited states in fission fragments.

The design of the new plunger will be discussed, as will the successful commissioning experiment performed at the IPN Orsay tandem. A first physics campaign performed during the autumn 2012 at the IPN Orsay Tandem laboratory will be presented. During this campaign experiments performed to measure the lifetimes in exicted states in ^{170}Os and ^{168}W were performed, as well as an experiment to meausure g-factors using the time dependent recoil in vacuum technique adapted for radioactive beams. Finally will future plans be touched upon.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Decay spectroscopy of exotic nuclei at RIBF

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β-decay spectroscopy is a powerful method of shedding light on the evolution of nuclear structure toward extreme neutron-to-proton ratios. The decay properties of neutron-rich nuclei are also essential to model the astrophsycal rapid-neutron-capture process (r process), one of the main and yet mysterious nucleosynthesis process operating in the universe.

The recent beam developments at RIBF [1], along with the installation of the EUROBALL γ-ray detector [2] have made new exotic proton- and neutron-rich regions of the nuclear chart accessible to decay-spectroscopy experiments. The EURICA project (EUROBALL RIKEN Cluster Array) has been launched in 2012 with the goal of performing $\beta\gamma$ spectroscopy in these regions [3]. EURICA is a high priority project for RIBF, made possible thanks to the contribution of a worldwide nuclear physics community.

Two experimental campaigns have been successfully performed in 2012 using fragmentation of ^{124}Xe beam and in-flight-fission of ^{238}U beam, respectively. The β- and γ-decay properties of exotic nuclei, such as β-decay half-lives, β-delayed γ rays, and isomers, have been measured for the $N = Z$ nuclei ^{98}In, ^{96}Cd, and ^{94}Ag and in the vicinity of ^{78}Ni [4], ^{128}Pd, and ^{138}Sn.

This contribution highlights the experiments performed and the future perspective of the EURICA project.

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* Supported by the EUROBALL Owners Committee, the PreSpec Collaboration, and the RISP Project at IBS

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Recent Experimental Studies of Nuclear Triaxiality in A∼160 Region

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Significant progress has been made in the past decade in the study of nuclear triaxiality. The wobbling mode, a finger print of nuclei with stable triaxiality, has been identified in several odd-A Lu and Ta isotopes around $A \sim 165$, see, e.g., Ref. [1]. Triaxial strongly deformed (TSD) bands based on the quasiparticle excitations have also been observed in odd-odd Lu isotopes. A number of theoretical investigations indicate that Hf nuclei near ^{166}Hf could be the best candidates for TSD structures with $(\varepsilon, \gamma) \approx (0.4, 20^\circ)$. However, only two TSD bands were observed in ^{168}Hf [2], which are very weak and could not be linked to known levels. Recently we have performed a Gammasphere experiment for ^{164}Hf at ATLAS [3]. Two new bands exhibit exotic properties, e.g., they have large initial aligned angular momentum ($>$20 $\hbar$) and do not undergo a proton crossing at $\hbar\omega \sim 500$ keV that is seen in other normal deformed bands. The distinctive behavior indicates that the bands are built upon separate potential energy minimum which involves high-j intruder proton orbitals. The bands are stronger than the TSD bands in ^{168}Hf by an order of magnitude and cross the yrast line at spin 32, as compared to spin $\sim$48 in ^{168}Hf. The bands do not assemble a family of wobbling excitation. The results will be compared with theoretical calculations, the possibility of wobbling excitation in even-even nuclei will be discussed.

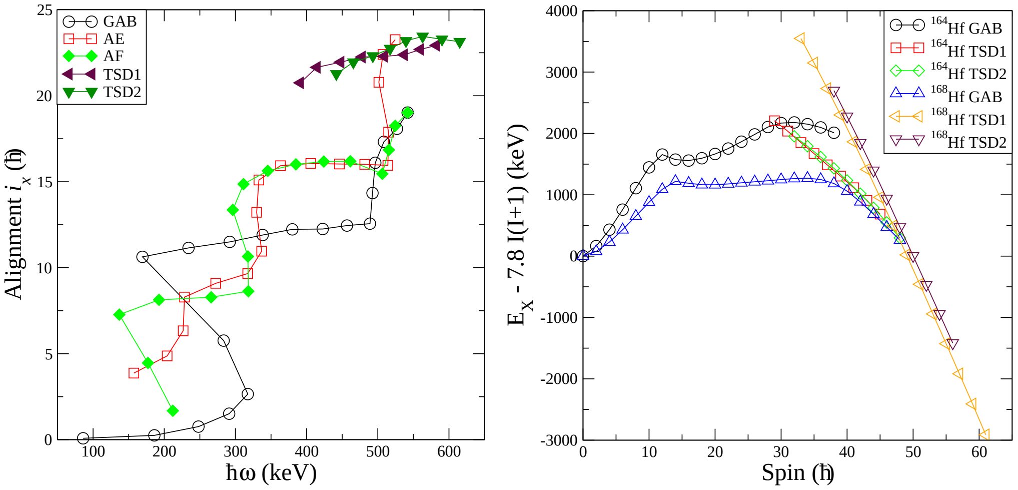

Figure 1: *Left: Aligned angular momenta as a function of rotational frequency for the new TSD bands in* ^{164}*Hf. Harris parameters* $J_0 = 15\ \hbar^2/MeV$ *and* $J_1 = 65\ \hbar^4/MeV^3$ *were used to subtract the angular momentum of the rotating core. Right: Excitation energies, minus a rigid-rotor reference, as a function of spin for the bands in* ^{164}*Hf and* ^{168}*Hf. The spins of* ^{168}*Hf bands are uncertain [2].*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Survey and Evaluation of Isobaric Analogue States

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Isobaric analogue states (IAS) can be used to estimate the mass of nuclei belonging to isobars of the same isospin multiplet set. The *Atomic Mass Evaluation* (*AME*) had previously evaluated the experimental data used to establish the mass of these states. These masses were also used to establish a semi-empirical relationship between the members of any given mass multiplet via the *isobaric mass multiplet equation*, *IMME*. The experimental and IMME estimated IAS data have not been published in the *AME* since 1993 [1]. However, given the recognized importance of isobaric states, it has been decided to reactivate these IAS studies initially instigated by Aaldert H. Wapstra.

In this conference we will describe the reaction data used to establish the *IAS*. Cases where reaction data provide a better mass precision as compared to decay data will be presented. The particular cases of $N=Z$, $T=1$ ground states, and fragmented states will also be discussed. This work is an extension and update of the work carried out by Aaldert H. Wapstra until 2003.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Nuclei at the Edge of Chaos

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I present a quantum investigation of the regular and chaotic dynamics of medium mass (A>40) even-even nuclei in the framer of the neutron – proton interacting boson model (IBM-2), by means of a statistical analysis of the calculated theoretical nuclear levels in the energy range up to several MeV. Use is made of Random Matrix Theory to study the fluctuation properties of nuclear levels, and of Gaussian Orthogonal Ensemble (GOE) to obtain the nearest neighbor level-spacing distribution, since a nuclear system is a Wishart Ensemble invariant under both temporal inversion and rotations.

Results of refs.[1] and [2] have been extended and fourteen shape-phase transitions among all the possible nuclear dynamical symmetries have been investigated, corresponding to regular motion in the usual dynamical classical systems; Brody distributions were calculated for all the transitions and compared with Poisson and Wigner distributions. The very rich algebraic structure of IBM-2 allowed to carry out a careful and valuable analysis of regular and chaotic dynamics in nuclei, resulting in observations of broad nearly regular and completely regular regions between integrable limits of IBM-2 (see Fig. 1) and in confirming the existence of partial dynamical and critical point symmetries.

However, these symmetries alone are not able to fully explain the existence of a regular behavior in nuclei and the presence of limited islands of quasi chaotic motion, assuming energy and total angular momentum as 'control' parameters of the considered dynamical systems. But, if nuclei are considered self-organized quantum systems at the edge of chaos, the predicted about 200 states acting as strange attractors reduce to just four ones. Therefore, nuclei behave as quasi – regular dynamical systems at the edge of chaos and IBM-2 model acts as a minimal symmetry algebra in the order-to-chaos transitions.

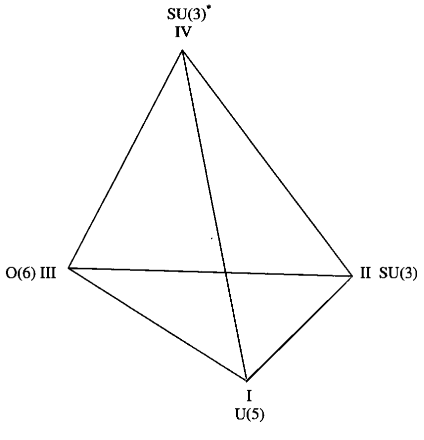

Figure 1: *Dynamical symmetries of IBM-2.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Probing core polarization around ^{78}Ni: intermediate energy Coulomb excitation of ^{74}Ni

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The study of the evolution of nuclear shells far from stability provides fundamental information about the shape and symmetry of the nuclear mean field. Nuclei with large neutron/proton ratio allow to probe the density dependence of the effective interaction. Indeed, it was recently shown that tensor and three-body forces play an important role in breaking and creating magic numbers [1]. Of particular interest is the region of ^{78}Ni where the large neutron excess coincides with a double shell closure. At this N/Z ratio one could expect an increase of the proton-neutron interaction strength that would modify the relative energies of the single particle states, thus reducing the $Z = 28$ energy gap [2]. In such a scenario, particle-hole excitations are expected to be strongly increased, driving to enhanced collectivity. The determination of the $B(E2)$ values of the low-lying transitions is therefore very important to measure these features and to constrain the interaction used for the shell model calculations.
We have recently measured the $B(E2; 0^+ \rightarrow 2^+)$ of ^{74}Ni in an intermediate-energy Coulomb excitation experiment performed at NSCL (MSU). The ^{74}Ni beam has been produced by fragmentation of the primary ^{86}Kr beam at 140 AMeV on a ^{9}Be thick target. The primary beam was provided by the Coupled Cyclotron Facility of the NSCL and the production reaction fragments were analyzed using the A1900 fragment separator. As a matter of fact, this setup produced a secondary "cocktail-beam“ containing ^{74}Ni ions with an intensity of ≈ 1 pps as well as higher intensity ^{77}Zn and ^{75}Cu fragments. An ^{197}Au foil of $640\ \mathrm{mg/cm^2}$ was used as secondary target. The scattered ions were identified by the focal plane detectors of the S800 spectrograph and coincidence γ-rays emitted by Coulomb excited ions were detected by the 4π CAESAR array. Taking into account a proper cut on the impact parameter and using the code DWEIKO for theoretical cross sections calculation, our results do not point towards an enhanced value for the transition matrix element. Compared to what already measured by Aoi and co-workers in [3], this result opens new scenarios in the interpretation of the shell evolution of the Z=28 isotopes.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Nuclear Tensor Force and Effective Pions in the Relativistic Hartree-Fock Formalism

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Nuclear properties concerning single-particle energies, spin-orbit splittings as well as total binding energies of several isotopic families, are investigated in the framework of nonlinear nuclear models based on the relativistic Hartree-Fock approximation. Our models include pions interacting with nucleons through a mixture of the pseudoscalar and pseudovector couplings and with a scalar field that dresses the π meson with an effective mass [1]. This effective mass influences the behaviour of the NN interaction due to pions, in particular, the strength of the tensor force. We determine the contribution of this force to the nucleon self-energies using two different methods. It is shown that a decreasing of the contribution of this tensor force considerably improves the single-particle spectrum of nuclei [2] and the total binding energy dependence on the mass number A for heavy nuclei.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Nucleon size effects in the parity violating electron scattering asymmetry

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Parity violating elastic electron scattering has been an important and probably an unique tool to investigate a series of fundamental properties, which include nuclear structure basic properties as the neutron distribution in nuclei, the strangeness content of the nucleon and the precise determination of the constants that define the Standard Model for the fundamental particles. At this respect, besides the experimental challenge that this type of measurement represents, some data were already obtained for ^1H, ^4He, ^{12}C and ^{208}Pb [1],[2],[3]. New and more precise experimental results are expected in the near future.

All those informations are present in the experimental extraction of the so called parity violating asymmetry and so a careful and precise knowledge of the nucleon as well as the nucleus structure as a whole are needed for the correct interpretation of the measurements. Here we are concerned with the sensitivity of the asymmetry to the finite size of the nucleon and to the contribution of the anomalous magnetic moment term which is present in the electromagnetic and weak neutral currents of the target, from which the asymmetry is strongly dependent. We solve the many-body nuclear dynamics through a relativistic mean field approach and the nucleon form factors are described by the parametrization defined in reference [4] . The final asymmetry is computed for $N = Z$ and $N \neq Z$ selected nuclei and is performed in the distorted wave approach, based on the Dirac equation solution subject to the strong electric and weak neutral fields of the nucleus. In the model calculation we include, besides the σ, ω and ρ mesons, also the δ field [5]. We consider non linear as well as density dependent couplings in the model Lagrangian. Our calculation includes, besides the low angle kinematics, an extrapolation to higher angles in order to investigate the role of the corrections and of the δ meson in future possible precise determinations of the neutron density distribution from neutron rich nuclei. We conclude that although the inclusion of the δ can be compensated by the parametrization of the model, as far as binding energy and charge radius of the nucleus is concerned, important effects appear in the weak charge distribution. As for the nucleon size effects , noticeable differences were found in the asymmetry.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Ab initio calculations for ^{12}C with JISP16

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We present recent results from no-core configuration interaction calculations for ^{12}C using the phenomenological two-body interaction JISP16 [1]. We calculate not only the ground state energy [2], but also the low-lying spectrum of both positive and negative parity states (with numerical uncertainty estimates). In addition to the energies, we also discuss other observables such as dipole and quadrupole moments, as well as transition rates for select electromagnetic transitions. We also compare the full isoscalar E2 strength distribution with available experimental results from inelastic alpha scattering experiments at Texas A&M University [3]. Finally, we demonstrate that several of these states can be understood in terms of rotational band structures.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Gamow-Teller strength in deformed nuclei within self-consistent pnQRPA with the Gogny force

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In recent years fully consistent quasiparticle random-phase approximation (QRPA) calculations using finite range Gogny force have been performed to study electromagnetic excitations of several axially-symmetric deformed nuclei [1] up to the ^{238}U [2]. Here we present the generalization of this approach to the charge-exchange nuclear excitations (pnQRPA). In particular we focus on the Isobaric Analog and Gamow-Teller resonances. As it is well known, these nuclear excitations play nowadays a crucial role in several fields of physics: nuclear physics (nuclear interaction), astrophysics (stellar evolution and nucleosynthesis) and particle physics (V_{ud} element of the CKM matrix, neutrinoless double beta decay). A comparison of the results with existing experimental data on Fermi and Gamow-Teller strength distributions, as well as predictions for some short-lived neutron-rich nuclei are presented. Special attention is paid to β-decay half-lives calculations for which comparisons with experimental data and predictions for isotone chains relevant for r-processes [3] are presented.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Change of radius of oxygen isotopes with an mechanism of enlarged core

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Properties of nuclei, such as binding energy, level scheme, transition, and radius have been investigated. In the drip-line region of the oxygen isotopes, the abrupt increase of the r.m.s.radius at ^{23}O is observed from the analysis of the reaction cross section [1]. The different point of the ^{23}O case is that the separation energy of ^{23}O is not so small compared to other typical halo nuclei. It can be considered that the large radius is constructed by not a simple picture with weakly-bound valence neutrons around the core nucleus. Contrary to the previous experiments [1], a recent measurement of the interaction cross section of the oxygen isotopes shows a rather small value of the radius of ^{23}O [2].

For study of the structures of the oxygen isotopes and other weakly bound nuclei, we developed an m-scheme approach of the cluster-orbital shell model (COSM) [3]. Using this COSM approach, we studied the oxygen isotopes and isotopes with $N = 8$ and qualitatively explained the origin of the abrupt increase of the r.m.s.radius as the number of valence nucleon increases [4]. A remaining problem is to understand the relation between the radius and binding energy. From ^{17}O to ^{22}O, the radius of oxygen isotopes can be reproduced by a fixed-size core nucleus and valence neutrons. On the other hand, for ^{23}O and ^{24}O, a broad core-size is suitable to describe the large radius of these isotopes.

In order to understand the property of the oxygen isotopes in the view point of the radius and binding energy, we introduce a coupled-channel picture for the structure of the ^{16}O-core [5]. This coupled-channel model successfully reproduce the radius of oxygen isotopes. For the nucleons in core nucleus, the Pauli forbidden states are applied, and the orthogonality condition model is introduces to the valence nucleon space.

The relation between the structure of the core nucleus and the presence of valence nucleons will be given in the COSM frame work. And the mechanism of the radius of the nucleus and enlargement core size will be discussed.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

In-beam γ-ray spectroscopy of ^{38,40,42}Si

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D. Jenkins[12], N. Kobayashi[13], Y. Kondo[13], R. Krücken[7], T. Le Bleis[14,15], G. Lee[13], A. Matta[16],
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Excited states in the nuclei ^{38,40,42}Si have been studied using in-beam γ-ray spectroscopy following multi-nucleon removal reactions [1] to investigate the systematics of excitation energies along the $Z = 14$ isotopic chain. The $N = 28$ isotope ^{42}Si can be regarded as a magic nucleus in the traditional shell model since a large energy gap exists at $N = 28$ due to the spin-orbit splitting. The disappearance of the $N = 28$ shell closure together with a large deformation, however, has been suggested from the observation of a low energy 2_1^+ state [2]. Several experiments have been performed to investigate the structure of ^{42}Si so far [2-5], but no experimental data have been reported on higher-lying states, which may contribute valuable information on the nature of the collectivity and/or shell evolution. In order to study these states, we performed multi-nucleon removal reactions with radioactive isotope beams of ^{40}S and ^{44}S at the RI Beam Factory accelerator complex operated by the RIKEN Nishina Center and CNS, University of Tokyo. Owing to the high secondary beam intensities, several γ-ray lines, which include candidates for the $4_1^+ \to 2_1^+$ tranditions, were observed for the first time in addition to the $2_1^+ \to 0_{g.s.}^+$ γ-ray transitions. We will report on the tentative spin-parity assignments of the observed excited states and discuss the evolution of nuclear structure toward the $N = 28$ isotope ^{42}Si, where the magicity loss was previously suggested [2,3]. A part of results were reported in Ref. [1].

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Nuclear pairing from realistic forces: singlet channels and higher partial waves

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The pairing gaps [1] in isospin-symmetric nuclear matter and neutron matter are investigated using the chiral nucleon-nucleon potential at the N^{3}LO order in the two-body sector [2] and the N^{2}LO order in the three-body sector [2,3]. We have developed a numerical code [4], based on the separation method introduced in Ref. [5], in order to study both the singlet channels ($^1S_0$) and higher partial coupled waves ($^3P_2$-$^3F_2$ and $^3S_1$-$^3D_1$). The role of three-body forces and other many-body correlations is discussed in comparison with available *ab-initio* and microscopic calculations [1,6] whenever is possible.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Proton inelastic scattering study on ^{30}Ne and ^{34,36}Mg isotopes

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The quadrupole deformations of neutron-rich even-even neon and magnesium nuclei around ^{32}Mg were studied via the proton inelastic scattering at 45 MeV/nucleon on a liquid-hydrogen target by in-beam γ-ray spectroscopy with inverse kinematics. By measuring de-excitation γ rays from interested nuclei, the populations of the first 2^+ states were determined with considering the feedings from upper excited states. The deformation lengths were extracted by comparison with angular-integrated cross sections and distorted-wave calculations.

The experimental reports on the neutron-rich boundary of island-of-inversion region were about the excitation energy of 2^+_1 state in ^{32}Ne and ^{36}Mg. The 2^+_1 levels in ^{32}Ne, ^{36}Mg are identified to be at 722(9) keV [1] and 660(6) keV [2], respectively. Those nuclei are suggested to have intruder configuration, that is, to be located in the island of inversion.

In this study, we take notice of the evolution of quadrupole deformation of neutron-rich nuclei in this deformation region. Figure 1 shows obtained γ-ray spectra in ^{30}Ne and ^{34,36}Mg. The cross sections to the 2^+_1 states in ^{30}Ne and ^{34}Mg were reported to be 30(18) mb by Yanagisawa *et al.* [3], and 111(37) mb by Elekes *et al.* [4], respectively. In ^{30}Ne, the present result was preliminarily 39(5) mb, which is consistent with the previous result. In ^{34}Mg, the cross sections to the 2^+_1 state were preliminarily determined to be 63(5) mb. This study improved the accuracy of the cross sections reported in the previous works. In ^{36}Mg, the cross section to the 2^+_1 state were preliminarily determined to be 48(8) mb. This value is smaller than that in ^{34}Mg, although the excitation energies of the 2^+_1 states in those nuclei are almost same.

In our talk, the evolution of quadrupole deformation around ^{32}Mg is discussed by comparing the present results with the shell-model and AMPGCM calculations.

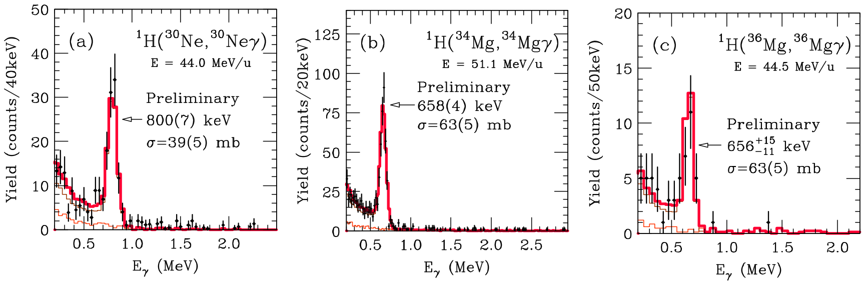

Figure 1: Gamma-ray Spectra in (a) ^{30}Ne, (b) ^{34} Mg and (c) ^{36}Mg.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Direct mapping of shell effects in the heaviest elements

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Superheavy elements ($Z \geq 104$) owe their existence to nuclear shell effects that stabilize their nuclei against immediate disintegration by spontaneous fission. The existence of an "island of stability" far away from then known nuclei was predicted soon after the nuclear shell model was developed. Current experimental evidence on nuclei of elements up to $Z = 118$ has confirmed the general concept; however the exact location and extension of this island are still not known. The role of the shell effects is crucial for the heaviest elements, yet until recently, high-accuracy direct experimental data on their strength was hardly available. Valuable information on the evolution of the binding energies on the way to the island comes from high-precision mass measurements. These allow direct measurements of binding energies also of transuranium nuclides, and thus give direct access to the strength of shell effects. Recently, the masses of the nuclides $^{252\text{-}255}$No and ^{255,256}Lr have been measured with high accuracy by use of the Penning trap mass spectrometer SHIPTRAP at GSI Darmstadt. The results provide experimental binding energies which allow mapping of the shell effects at the deformed shell closure $N = 152$. The experimental values for the shell gap parameter are more precise than the differences among different theoretical approaches based on, e.g., microscopic-macroscopic or relativistic mean-field models. Therefore, they provide a stringent benchmark for nuclear models used to describe the superheavy elements. The present results, recent developments and future measurements will be discussed.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Systematics of band moment of inertia of yrast and excited SD bands of even-even nuclei in A=150 mass region

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A four parameter formula has been applied to all the yrast and excited superdeformed (SD) bands of even-even nuclei in the A=150 mass region to obtain band moment of inertia J_0. In even-even nuclei, total four yrast SD bands and sixteen excited SD bands have been fitted. The measured Q_t- values and hence the axes ratios have been used to calculate the rigid body J_0 values and compare with the fitted values of J_0. It is interesting to look at the yrast SD band ^{152}Dy (1), the doubly magic SD nucleus and the first one to be discovered that the J_0 values are quite larger than that extracted from Q_t measurement. We found that all the excited SD bands in even-even nuclei are signature partner SD bands because the J_0 value of each signature partner SD band is almost identical. Among all these excited SD bands, ^{150}Gd (4) is found to be super-rigid in nature having J_0 value larger than that observed from the measured Q_t-value.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Collectivity in neutron-rich Co and Mn isotopes going towards $N = 40$

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In the recent years a large effort has been devoted to the study of shell evolution in neutron-rich nuclei. These studies have been possible thanks to the improvements in experimental techniques, as state-of-the-art detector arrays combined with stable and radioactive beam facilities, that have boosted these studies through regions that were unaccessible before. In the last decade, for example, a large experimental an theoretical effort has been devoted to the study of the sub-shell closure $N = 40$ and the evolution of the magic number $N = 50$ for the Ni isotopic chain. Meanwhile the $N = 50$ ^{78}Ni excited states represent still nowadays an experimental challenge, the evolution of the sub-shell closure at $N = 40$, when taking away protons from the Ni core, has been thoroughly studied. I fact, it has been measured that, by removing protons from the $f_{7/2}$ shell below ^{68}Ni, the $N = 40$ subshell gap vanishes and a new region with large quadrupole deformation develops, as is the case for ^{66}Fe and ^{64}Cr [1,2]. A large theoretical effort within the shell-model framework has been done to describe this development of deformation and it has been shown that only by the inclusion of the neutron orbital beyond $N = 50$, $d_{5/2}$ the deformation can be reproduced in this so called new island of inversion [3,4]. In this work we have studied the low-lying excited states in the neutron-rich Co (one proton hole respect to Ni) where the coexistence of both collective (one proton $f_{7/2}$ hole coupled to the Fe core) and single-particle states (one proton $f_{7/2}$ hole coupled to the Ni core) are present [5,6]. We have also studied the excited states in neutron-rich Mn isotopes (three proton holes respect to Ni). The lifetimes of the excited states in ^{63,65}Co as well as ^{59,61}Mn have been measured employing the Recoil-Distance-Doppler-Shift method. The nuclei of interest were populated employing a multinucleon transfer reaction with a ^{64}Ni beam impinging onto a ^{238}U target, taking advantage of the state-of-art AGATA demostrator [7] to measure the γ rays. The experimental $B(E2)$ values have been compared with large-scale shell-model calculations, which lead us to draw some conclusions on the role of the $d_{5/2}$ and $g_{9/2}$ neutron orbitals in driving collectivity below ^{68}Ni.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Effect of the isoscalar and isovector pairing-strengths on the system energy of even-even nuclear systems

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Due to fast progress in Radioactive Ion Bean programs, the study of neutron-proton pairing effects has known a renewal of interest during the last decade (cf. e.g. [1-4]). Indeed, these effects that were negligible in "ordinary" nuclei must be taken into account in nuclei such as N≈Z of which the experimental study is now possible.

Neutron-proton (np) pairing effects may exist in two varieties: the isovector (T=1) and the isoscalar (T=0) pairing. The latter one has been less studied than the first one, in particular in realistic cases. Among others, the choice of the pairing-strengths is one of the difficulties encountered in the study of the isoscalar pairing.

The goal of the present contribution is to study numerically T=1 and T=0 neutron-proton pairing effects on the system energy as a function of the isovector and isoscalar pairing- strengths. With this aim, we used a BCS approach and considered even-even systems within the schematic one-level model.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Laser spectroscopy - optical probes for radioactive nuclei

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The study of exotic nuclear matter and related radioactive ion beam technologies is at the forefront of modern subatomic physics. Atomic physics techniques - more specifically, high resolution optical measurements of the atomic structure - readily yields fundamental and model-independent data on the structure of ground and isomeric nuclear states. The competition and balance between nuclear shell and collective effects results in a spectacular range of shapes and sizes within nuclear systems. Such shapes and structures perturb the atomic energy levels of atoms and ions at the ppm level and although this is a small absolute effect it is readily probed and measured by modern laser spectroscopic methods. These techniques are particularly suitable for the study of short-lived radionuclides with lifetimes as short as a few milliseconds, and production rates often only a few hundred isotopes/isomers per second.

In recent years, resonant laser ionization has become a mature technique, playing a key role in the selective production of radioactive nuclides at on-line isotope separator (ISOL) facilities. More recently, spectroscopy is being performed in-source, complementing the high-resolution collinear beams method by offering a means to probe even more weakly produced nuclei, with rates as low as a few atoms per second, albeit with lower resolution. In order to increase the resolution of these techniques new laser systems are being developed and different environments are being utilized which offer the most attractive perspective from the point of view of reduced atomic line broadening mechanisms. In this sense, gas jet laser spectroscopy is a novel technique yielding first promising results in its early stages of development.

In this talk I will review some of the recent progress in the field of laser spectroscopy at facilities such as ISOLDE, CERN, and at IGISOL-4, Jyväskylä. I will also discuss some of the most novel developments in the field of laser ionization and will conclude with a look at the current gaps in our knowledge and where the field of laser spectroscopy is proceeding in the future.

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^{72}Zn(d,^{3}He)^{71}Cu transfer reaction

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The series of copper isotopes (Z=29) is of prime interest for nuclear structure. The first 5/2 level in the odd isotopes, carrying most of the f5/2 proton strength, sharply drops in energy beyond N=40 and becomes the ground state in ^{75}Cu. The position and the strength distribution of the f7/2 spin-orbit partner is essential to understand the underlying mechanism of this effect, bent to have major implications for structure variations towards ^{78}Ni. With this purpose in mind the ^{72}Zn(d,^{3}He)^{71}Cu transfer reaction was performed at Ganil with the Must-2 particle array, giving precisely access to proton-hole states in copper. The data are currently under analysis. A first excitation energy spectrum was obtained with two main peaks, and the respective angular distribution was also measured. The first peak centered at 232.0 ± 63.8 keV is compatible with a mixing of the $p_{3/2}$ ground state and the first excited state $f_{5/2}$ at 534 keV. On top of that the associated angular distribution is also compatible with a mixing of $L = 1$ and $L = 3$. The second peak centered at 4.52 ± 0.09 MeV shows an angular distribution compatible with a $L = 3$ state.

It was also possible with this setup to measure the ^{72}Zn(d,t)^{71}Zn transfert reaction. We see two main peaks in the excitation energy spectrum of ^{71}Zn. The angular distribution of the first one centered at -49.0 ± 55.3 keV suggests a mixing of $L = 1$ and $L = 2$ state, while for the second peak the angular distribution shows a $L = 2$ state centered at 1.06 ± 0.08 MeV.

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Giant Dipole Resonance in ^{28}Si+^{116}Cd reaction

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The phenomenon of giant dipole resonance (GDR) built on excited states [1] in nuclei continues to be a subject of active research by many groups. Experiments have been carried out to study the dependence of temperature and angular momentum on GDR observables like centroid, width and strength [2]. We have carried out experiments to study the GDR width evolution in ^{144}Sm nuclei [3] at different excitation energies using Pelletron + superconducting LINAC booster facility at Inter University Accelerator Centre (IUAC), New Delhi. ^{28}Si+^{116}Cd reaction was used to populate ^{144}Sm at incident beam energies of 125 to 170 MeV. GDR widths are deduced from the analysis of the GDR gamma ray spectra obtained by exclusive measurements using a 10×12 inches large NaI(Tl) detector in coincidence with a 27 element NaI(Tl) multiplicity filter (TIFR sum-spin spectrometer) in soccer ball geometry covering a solid angle of $\sim 80\%$ of 4π sr. Detector responses were simulated using monte-carlo simulation package GEANT4 [4]. The angular momentum spanned in the reactions ranges from 25 to 70 $\hbar$. The statistical model code CASCADE [5] incorporating the GDR parameters has been used for calculations and extraction of GDR parameters. The spectra showing GDR strength for different fold windows are shown below. Results of measurement at other energies also will be presented in the conference.

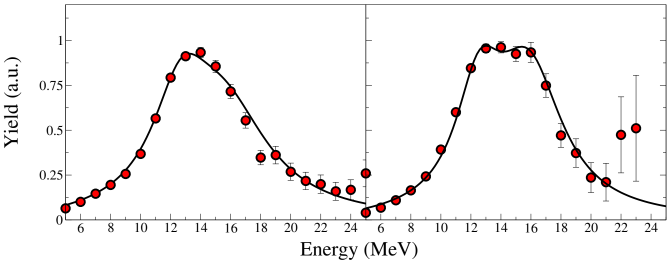

Figure 1: *GDR strength functions for fold 9-10 (left) and fold 13-14 (right) in the reaction ^{28}Si+^{116}Cd at 140 MeV beam energy. Circles are experimental points fitted with CASCADE and solid line is the theoretical calculation. Linearized plots are generated using approach given in [2].*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Two-neutron-transfer to ^{178}Yb and Population of ^{178m2}Hf via Incomplete Fusion

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The DIAMANT light-charged-particle detector from ATOMKI has been coupled with the AFRODITE gamma-ray spectrometer at iThemba LABS in a collaboration enabled by a bilateral agreement between the governments of South Africa and Hungary. This has facilitated the study of incomplete fusion reactions in the bombardment of aYtterbium-176 target with a beam of 50 MeV Lithium-7 ions. The beam was generated as a collaborative effort between ion source experts at iThemba LABS and the Flerov Laboratory for Nuclear Reactions (FLNR) of the Joint Institute for Nuclear Reactions (JINR), Dubna under an ongoing intergovernmental agreement, enabling a Tri-Partite Alliance to be formed between experimentalists from the respective institutions in the three countries.

Particle-Identification (PID) spectra from DIAMANT generated from the ATOMKI custom-built VXI electronics clearly show the detection of protons, tritons and alpha particles, which, when gated on, allowed the selection of gamma-ray coincidences detected with AFRODITE when the respective complementary Helium-6, Helium-4 (α) and triton fragments fused with the target.

Analysis of the charged-particle-selected gamma-ray coincidence data enabled the identification of Hafnium-180 in the proton-gated E_γ -E_γ correlation matrix, as well as Hafnium-178, including the band based on the $T_{1/2}$ = 31a $K^\pi = 16^+$ four-quasiparticle state. Hafnium-178 is also evident in the triton-gated matrix, which suggests that this nucleus is populated via two incomplete fusion channels, this one in which the fused fragment is Helium-4, and the other in which a Helium-6 neutron-rich fragment fuses with the Ytterbium-176 target.

The relative contribution from the (^{7}Li,p4n) fusion evaporation channel is at present unclear, but there is other evidence for Helium-6-induced reactions in the population of neutron-rich Ytterbium-178 whereby two neutrons have been transfered to the target. The ground-state band of Ytterbium-178 can be clearly observed in both the proton-gated and alpha-gated matrices, which is consistent with the ^{176}Yb(^{7}Li, αp)^{178}Yb reaction. The deuteron yield is comparitively weak which has hampered the unambigous confirmation of the ^{176}Yb(^{7}Li, αd)^{177}Yb reaction, though analysis is still in progress.

The comparatively strong population of Hafnium-178 via the two reaction channels discussed above has allowed the population ratio I_γ(proton-gated)/ I_γ(triton-gated) of the ground-state, two-quasiparticle $K^\pi = 8^-$ and four-quasparticle $K^\pi = 14^-$ and $K^\pi = 16^+$ bands to be extracted as function of spin . There is evidence for a marked increase in relative population of the $K^\pi = 16^+$ band when compared to the other lower-spin band structures.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Kinematically complete measurements of Coulomb breakup of Borromean halo nuclei at the SAMURAI facility at RIBF

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We report here on some of the first results on kinematically complete measurements of breakup of neutron drip line nuclei using the recently commissioned large-acceptance multi-purpose spectrometer SAMURAI (**S**uperconducting **A**nalyser for **MU**lti-particles from **Ra**dio-**I**sotope Beam) facility, at the new-generation RI beam facility, RIBF, at RIKEN. The experiment was aimed at probing the two-neutron Borromean halo nuclei, focusing on ^{19}B and ^{22}C, the exclusive measurements of which were only made possible by the use of the large-acceptance SAMURAI facility, coupled with secondary beams of unequaled intensity (100 and 15 pps, respectively). In the case of ^{22}C much attention has focused on the possibility that it has the largest halo known, as inferred from an extremely large reaction cross section [1]. In addition, ^{22}C may also exhibit features consistent with the new magic number N=16, as was recently suggested by our inclusive measurement of the momentum distribution of ^{20}C following breakup on a C target [2]. In the case of ^{19}B, in addition to a Borromean character, interest centers on the possibility of a 4-neutron halo-like structure. Coulomb breakup is a powerful probe of haloes owing to the unique strong low-energy electric dipole strength (soft $E1$ excitation), sensitive to the halo part of the radial wave function. It has also been demonstrated that a kinematically complete measurement of Coulomb breakup can be used to study the halo neutron correlations [3,4]. The Coulomb breakup of ^{22}C and ^{19}B was studied, as part of the first round of SAMURAI experiments, in May 2012. The momenta of all the beam-like reaction products ^{20}C(^{17}B)+n+n were measured in coincidence following breakup on a thick Pb target at about 240 MeV/nucleon. In this presentation, in addition to the results from this work, those obtained for ^{14}Be, with the highest statistics ever obtained, will be discussed. Finally, we will also present some perspectives on future projects using the SAMURAI facility.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Spectroscopy of ^{98}Ru

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Even ruthenium isotopes have been the object of a variety of theoretical analyses along the years, ranging from microscopic calculation [1] to critical-point symmetry [2]. However, for some isotopes, an extended comparison of experimental and calculated values was prevented by the lack of many important spectroscopic data, such as definite spin-parity assignment to low-lying levels. To provide new spectroscopic data useful to the interpretation of the properties of low-lying states in the ruthenium chain, we have performed γ-γ coincidence, γ-γ angular correlation and K-internal conversion coefficient measurements in ^{98}Ru, populated via the ^{97}Mo(^{3}He,2n) reaction. An improved knowledge of the decay scheme up to 4.0 MeV was obtained: some spin-parity assignments were deduced and the value of E2/M1 mixing ratios for the most intense transitions were determined. Coincidence measurements were performed by means of an apparatus which employes five HPGe detectors mounted on a circular track, at adjustable angular positions and distances from the target. Cone-shaped lead shields (internally copper–lined) were utilized to define the acceptance of the detectors and to minimize gamma cross–scattering effects. The layout of the apparatus is shown in Fig. 1. Internal conversion electrons were detected by means of a magnetic transport system which deflects electrons onto a Si(Li) detector cooled to liquid nitrogen temperature. The momentum acceptance of the system was $\Delta p/p = 18\%$ (Full Width Half Maximum).

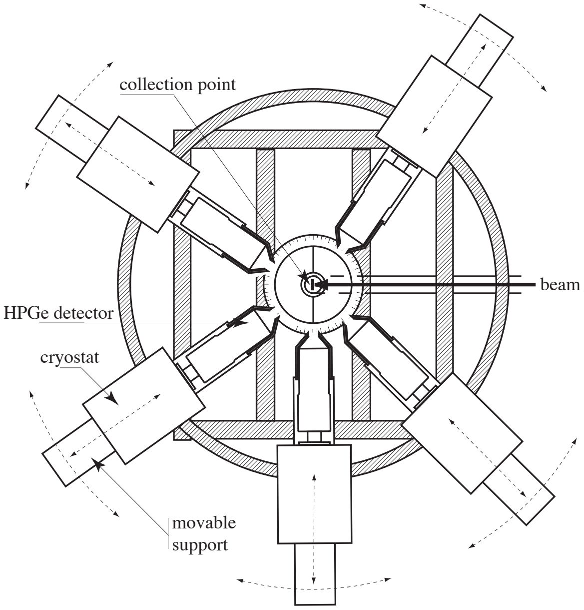

Figure 1: *Schematic view of the apparatus utilized in the angular correlation measurements.*

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g factor measurement of the 2_1^+ state in ^{138}Ce using Recoil Into Vacuum

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The study of collective isovector states gives information on the proton-neutron interaction, responsible for driving the collectivity in a nucleus. The stability of such collective excitations are often eroded by the underlying single-particle structure showing an interesting interplay between the collective and single-particle behavior of the nucleons. This mutual competition results in the evolution of nuclear properties. In a recent study of mixed symmetry states in $N = 80$ isotones, namely ^{134}Xe [1], ^{136}Ba [2] and ^{138}Ce [3] a large effect of the single-particle structure on the evolution of these excitations was observed. The $M1$ transition strength between the ($2^+_{1,ms}$) state and the nearby lower-lying ($2^+_{1,fs}$) state in ^{138}Ce was found fragmented while in ^{134}Xe and ^{136}Ba the strength remains largely unfragmented. The reason for the observed instability of ($2^+_{1,ms}$) state in ^{138}Ce was attributed to the presence of a $\pi g_{7/2}$ subshell closure [3]. The proposed concept of "shell stabilization" [3] suggests that mixing of the one-phonon mixed symmetry state with the neighboring multiphonon 2^+ excited states with similar proton configurations must occur in ^{138}Ce, whereas in ^{134}Xe and ^{136}Ba, the ($2^+_{1,ms}$) remains relatively pure. To prove the validity of this concept and to probe the configurations of the low-lying excited states, a measurement of the g factor of the 2_1^+ in ^{138}Ce was performed.

The low-lying excited states in ^{138}Ce were populated via inverse Coulomb excitation on a 1 mg/cm^2 thick ^{24}Mg target at ATLAS, ANL. To measure the g factor, the Time Dependent Recoil Into Vacuum technique (TDRIV) was employed and attenuation of the angular distribution of emitted $2_1^+ \rightarrow 0^+$ γ rays was measured. The experimental setup included the Yale plunger device and Gammasphere. Principle of TDRIV technique will be discussed along with the results.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Critical analysis of the pygmy giant resonance nature: the crossover with the vortical toroidal flow

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During the last decade we observe an increasing interest in the E1 low-energy strength, often denoted as the ”pygmy dipole resonance” (PDR) [1]. The PDR can be related to the neutron skin in nuclei and density dependence of the nuclear symmetry energy, which in turn may be important for the isospin-dependent part of the nuclear equation of state (EOS) and various astrophysical applications.

Despite a great number of publications on the PDR, its properties (e.g. collectivity) and nature (e.g. the actual velocity flow) are not yet well established and may be disputed [2,3]. In the present study [2], we critically inspect the familiar view of the PDR as an oscillation of the neutron excess against the nuclear core. The exploration is performed within the random - phase - approximation (RPA) using Skyrme forces in the fully self-consistent manner [4]. The strength functions, transition densities and velocity fields are explored.The possible contributions of the toroidal (vortical) and compression (irrotational) modes [5] to the PDR region are scrutinized.

The analysis for ^{208}Pb reveals a complex PDR structure. In the low-energy PDR part, 6.0-8.8 MeV, the dominant isoscalar toroidal flow is found. So, this part mainly represents a vortical excitation! The higher PDR part, 8.8-10.5 MeV, is more complicated and demonstrates a mixed isoscalar/isovector toroidal/compression flow. The velocity fields do not support the familiar PRD picture as an oscillation of the neutron excess against the nuclear core.

These findings, especially the dominance of the toroidal (vortical) flow, compel to revise a customary treatment of the PDR and its role in various problems (EOS, etc). We discuss these points as well as perspectives of different reactions, first of all (e,e'), in clarification of the PDR origin. The dependence of the PDR/toroidal interplay on the neutron excess, nuclear shape, and mass region is analyzed.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

First observation of an isomeric state in proton drip-line nucleus ^{26}P

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The proton drip-line nucleus ^{26}P has attracted much interests since it is a candidate of proton halo nucleus [1] and is related to the astrophysical problems such as the rp-process nucleosynthesis and X-ray bursts [2]. However, the experimental facts for ^{26}P have been little known yet. In 2004, the β-decay study by Thomas $et\ al.$ reveals that the spin-parity of the ground state ($J^{\pi}_{\rm g.s.}$) and the proton separation energy (S_p) of ^{26}P would be 3^+ and only 0 ± 90 keV, respectively [3]. To date, any bound excited states in ^{26}P have not been reported yet. On the other hand, the $J^{\pi}_{\rm g.s.}$ of the mirror nucleus ^{26}Na is also 3^+ and there is a low lying isomeric state (i.s.) at the excitation energy of 80 keV with $J^{\pi}_{\rm i.s.} = 1^+$. Assuming the mirror symmetry, the ^{26}P may also have an isomeric state at small excitation energies. To investigate the existence of the isomeric state in ^{26}P, the -ray measurement have been carried out at NIRS-HIMAC. Two HPGe detectors were used to observe rays from ^{26}P stopped in a acrylic with a thickness of 5 mm. As shown in Fig. 1, a new transition has been found, for which the -ray energy and half-life are $E_\gamma = 164.4 \pm 1$ keV and $T_{1/2} = 120 \pm 9$ ns, respectively. This fact suggests that the excitation energy of the -decaying isomeric state is larger than S_p. Comparing the experimental reduced transition probabilities of ^{26}Na and ^{26}P with theoretical ones calculated by the shell model with the USDA interaction, the $J^{\pi}_{\rm i.s.}$ of ^{26}P is implied to be 1^+.

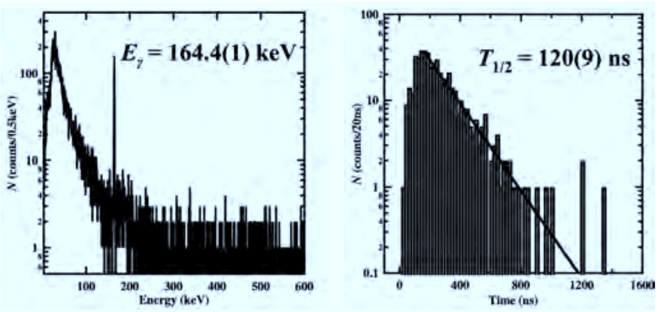

Figure 1: *Observed -ray energy (left) and decay time (right) spectra.*

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Decay spectroscopy of very neutron-rich nuclei at RIBF

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β-decay spectroscopy is a powerful method of shedding light on the evolution of nuclear structure toward extreme neutron-to-proton ratios. Obtaining the decay properties of neutron-rich nuclei is also essential in understanding the mechanism of a rapid-neutron-capture process (r process) nucleosynthesis, which is responsible for the production of elements heavier than iron in the universe.

Recently, the Radioactive Isotope Beam Factory (RIBF) at RIKEN Nishina Center starts providing very exotic nuclei by means of the fragmentation or in-flight fission method of high-intensity beam [1]. Bringing together the world's largest γ-rays detectors (Euroball germanium cluster detectors) [2], a new project EURICA (EUROBALL RIKEN Cluster Array) has been launched with the goal of performing $\beta\gamma$ spectroscopy of exotic nuclei [3]. A campaign experiment of neutron-rich nuclei with EURICA was conducted successfully using 6-12 pnA of an ^{238}U-beam in November-December, 2012. The β- and γ-decay properties of neutron-rich nuclei, such as β-decay half-lives, β-delayed γ, and isomers, have been measured in the vicinity of ^{78}Ni and ^{128}Pd along the r-process path. This paper summarizes the experimental high-lights of beta-decay study and future perspectives at RIBF.

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* Supported by the EUROBALL Owners Committee, the PreSpec Collaboration, and the RISP Project at IBS

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Study of the properties of the superheavy nucleus Z = 117 produced in the ^{249}Bk + ^{48}Ca reaction

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The reaction of ^{249}Bk with ^{48}Ca have been reinvestigated to provide new evidence for the discovery of elements 113, 115, and 117 on a larger number of events. The experiments were performed during April–October, 2012, at the Dubna Gas-Filled Recoil Separator at five projectile energies and with a total beam dose of ^{48}Ca of about 4.6×10^{19}. Two isotopes ^{293,294}117 were synthesized in the ^{249}Bk+^{48}Ca reaction, providing excitation functions and α-decay spectra of the produced isotopes that establishes these nuclei to be the products of the 4*n*- and 3*n*-evaporation channels, respectively ([1] and this work). Decay properties of ^{293,294}117 and of all the daughter products agree with the data of the experiment in which these nuclei were synthesized for the first time in 2010 [2]. The new ^{289}115 events, populated by α decay of ^{293}117, demonstrate the same decay properties as those observed for ^{289}115 produced in the ^{243}Am(^{48}Ca,2*n*) reaction [3] thus providing cross-bombardment evidence. In addition, a single decay of ^{294}118 was observed from the reaction with ^{249}Cf – a result of the in-growth of ^{249}Cf in the ^{249}Bk target. The obtained results are compared with the data from previous experiments aimed at the synthesis of elements 115 [3], 117 [1,2], and 118 [4].

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Extended Brueckner-Hartree-Fock theory and importance of pions in nuclei

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One of the fundamental subjects of Nuclear Physics is to understand basic structure of nucleus as a consequence of bare interaction among constituent particles. The nuclear interaction is characterized by strong tensor force induced by pion-exchange interaction and short-range repulsion originated from the quark degrees of freedom in nucleon. We present a nuclear many-body theory with explicit treatment of these two indispensable forces to handle the heavier nuclei than mass number ^{12}C. We would like to show the importance of pion in construction of the basic structure of nucleus by using this framework.

For this purpose we have to extend the Hartree-Fock (HF) variational model space to include all possible 2 particle 2 holes (2p-2h) states, which are able to treat the tensor correlation with high momentum components originating from pseudo-scalar nature of pions. We take a variational principle for the ground state wave function, where the amplitudes of the 2p-2h states, the single-particle states in the Fermi-sea and the correlation function for taming the short-range repulsion are decided by energy minimization. In this theory the single-particle states in the Fermi-sea are obtained self-consistently under the effect of those two characteristic correlations.

The variational equation of this theory for the single particle states in the Fermi-sea has a similar structure as the Brueckner-Hartree-Fock theory and we name the theory as an extended Brueckner-Hartree-Fock (EBHF) theory. An important feature of this theory is that the part of the HF space cannot be normalized. It means that the amounts of the low momentum components (HF) are reduced, and some probabilities for high momentum components caused by the tensor force and short-range repulsion are given. Furthermore, a concept of the total energy appears in the variational equation in the EBHF theory. Finally, this theory can treat many-body correlations caused by two-body interactions by including all the possible matrix elements among 2p-2h states.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Rotational band in ^{12}C based on the Hoyle state

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The ^{12}C state 0^+_2, E* = 7.65 MэB (the Hoyle state) attracts attention for many years and still remains to be some kind of mystery. Observation of the excited states genetically connected with it might provide new important information about its structure. Very recently two new excited states: 2^+_2 (9.84/9.6 MeV) [1] and, possibly, 4^+_2 (13.3 MeV) [2] were discovered.

In this paper: 1) The diffraction radii R_{dif} of the 2^+_2 state was extracted from the positions of the minima and maxima of the L = 2 components obtained in [1,3] from the decomposition of the inelastic scattering cross-sections corresponding to ~ 10 MeV excitation energy of ^{12}C. The R_{dif} values occurred to be similar to those of the Hoyle state and well fitted the corresponding energy dependence [4] (Fig.1). Application of the modified diffraction model (MDM) [4] gave the value $\langle R \rangle = 3.20 \pm 0.23$ fm of the *RMS* radius of the state. It is close to $\langle R(0^+_2) \rangle = (2.89 \pm 0.04$ fm [4]) and much smaller than predicted by the α-condensate model [5].

2) The inelastic ^{12}C + α cross-sections leading to the ^{12}C levels with the excitation energies in the vicinity of 14 MeV were measured at E(α) = 65 MeV. Besides a well-known 14.08 MeV, 4^+ state a new broad (Γ = 1.4 MeV) state was observed at E* = 13.75 MeV (Fig.2). The angular distributions are in their main features similar and consistent with $I^\pi = 4^+$ assignment for both levels. The MDM and DWBA calculations aimed for extracting the radii values of the states are in progress. The sequence 7.65 – 9.6 – 13.75 MeV excellently fits the linear I(I+1) dependence. Thus, the obtained results clearly indicate to the rotation structure of the dilute Hoyle state and existing of a new rotational band in ^{12}C.

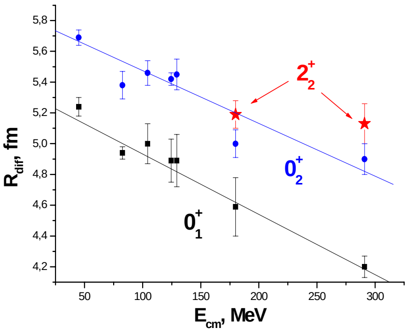

Figure 1: *Diffraction radii from ^{12}C(α,α')*

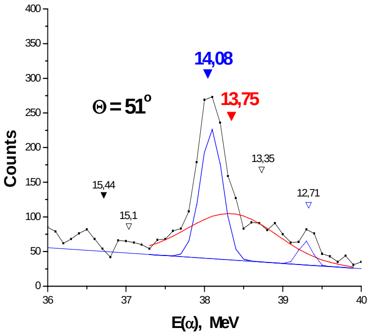

Figure 2: *Sample α-spectrum ^{12}C(α,α'),Eα=65MeV*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

New Pfaffian formulae for an overlap of multiple quasiparticle states

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Nuclear matter obeys superfluidity. Pairing correlations thus play an important role to determin the properties of the nuclear matter, including its "drop".

The drop is nothing but a finite nulcear system, whose structure is influenced by its deformed boundary and the pairing correlations coming from the nuclear interactions. Such a many-body fermionic system is known to be well described by a mean-field theory called the Hartree-Fock-Bogoliubov (HFB) theory.

It had been a long-standing problem to calculate an overlap of two HFB states, despite the discovery of the Onishi formula in 1966 [1]. The Onishi formula is the first compact formula enabling the analytical evaluation of the HFB overlap. But the formula contains a square-root operation for a determinant of a complex matrix, originating from the Bogoliubov transformation to deal with the nuclear pairing. This square-root operation brings an ambiguity to determin the sign of the overlap (the sign problem). The sign problem had repeled many challenges since the discovery of the Onishi formula, particularly at high spin [2].

In 2009, Robledo proposed a totally new idea to solve the sign problem [3]. He introduced a fermion coherent state and the Grassmann numbers to obtain a new formula in terms of the Pfaffian. It has not been known to nuclear physicists, but mathematicians unveiled the following property centries ago!

$$\mathrm{Pf}(A) = \sqrt{\mathrm{det} A}, \tag{1}$$

where A is a skew-symmetric matrix. A question is how to find a proper skew-symmetric matrix suitable for the nuclear physics. Robledo found that a bipartite expression of the creation and annihilation operators is a way to solve the problem, and obtained a Pfaffian formula

$$\langle \Phi_1 | \Phi_2 \rangle = \mathrm{Pf}(M_{12}), \tag{2}$$

where M_{12} is a barpite expression for the skew-symmetric matrix appearing in the HFB ansatz.

The authors extended Robledo's work to multiple quasiparticle excited states [4], including odd-mass systems [5], to be successful in finding new formulae. The mathematical structure of the formulae is a product of two Pfaffians. We found that our formulae corresponds an alternative manifestation of the generalised Wick's theorem, but in a more compact and systematic way. We also noticed that our formula gives a solution to the Balian-Brezin conjecture [6] proposed in 1969. It is interesting that the demonstration of the conjecture can be achieved with the help of the Pfaffian counterpart of the Lewis-Carroll formula (again centuries ago) [7].

We would like to present these new findings and an application of the fomrulae to nuclear physics problems.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Triaxial deformation and nuclear shape transition in ^{192}Au

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The A ~ 190 nuclei lie in a transitional region, where prolate-oblate shape change is expected to occur and the heavier isotopes are expected to have oblate shapes while the lighter neutron-deficient nuclei are prolate rotors. The structure of 192Au at high-angular momenta will be discussed. High-spin states of ^{192}Au studied with the ^{186}W(^{11}B, 5n) reaction have been populated at a beam energy of 68 MeV. Reaction γ-rays were detected in-beam with the YRAST Ball at the WNSL, Yale University [1,2]. The results will be discussed from a point of view of the development of triaxial deformations in the mass A ~ 190 region.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

First β-decay study of ^{66}Mn into ^{66}Fe

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In nuclei with large neutron to proton ratio, the changes of shell structure may lead to the vanishing of selected subshell gaps and the appearance of new ones. One of the regions of interest is the one below ^{68}Ni, where the competition of several effects distort the $N = 40$ subshell gap. For instance ^{66}Fe, two protons below ^{68}Ni, shows a very low-lying 2^+ state, which can be interpreted as increased collectivity for this nucleus. Along the chain of Fe even-even isotones, indications for a collective behavior arise from the 2^+ state energies and the B(E2) values [1]. The evolution of the B(E2) values in even iron isotopes points to a sudden increase of collectivity when approaching $N = 40$. This sudden onset of collectivity challenges the shell model, which can only reproduce the large quadrupole collectivity in this mass region by the inclusion of the neutron $1d_{5/2}$ orbital.

The filling of neutrons in the $g_{9/2}$ and $p_{3/2}f_{3/2}p_{1/2}$ orbitals gives rise to states with opposite parity and high difference in spin. This may lead to slow high-multipolarity transitions and the presence of lifetimes of the excited states in the nanosecond region which are suitable to direct measurement by time-delayed techniques. The Advanced Time Delayed $\beta\gamma\gamma$(t) method [2] is specially suited to measure half lives in the picosecond to nanosecond range, which allows for measurements of dynamic moments and mapping of collectivity at the $N = 40$ Fe nuclei.

The fast-timing ATD $\beta\gamma\gamma$(t) measurements were performed at ISOLDE in CERN, where neutron-rich Fe nuclides below ^{68}Ni populated by the β-decay of Mn isotopes were explored. Mass separated Mn beam was continuously deposited creating a saturated source, which included short- and long-lived activities coming from a number of radioactive decays. The measuring station included five detectors positioned in a close geometry around the beam deposition point. The fast timing β-detector was a 3 mm thick NE111A plastic scintillator placed directly in front of the radioactive source. The γ-ray detectors included two small fast-response $LaBr_3$(Ce) scintillators in the shape of truncated cones with 38.1 mm height, 38.1 mm diameter at the bottom and 25.4 mm diameter on the top, as well as two HPGe detectors with high relative efficiencies.

For the first time an in-depth study of the β-decay of ^{66}Mn to ^{66}Fe was performed. We will present a level scheme that confirms the previous seen gammas in ^{66}Fe and that expands it with a dozen new levels up to 3.6 MeV and over 20 new gammas. A small β-n branch has been observed. Our preliminary results are in agreement with the previously measured half life for the 573.5 keV level ($2^+_1 \rightarrow 0^+$) in [1]. Upper limits for the half lives of levels 834.1 and 2874.3 keV will be presented as well. With this information and theoretical calculations, tentative spin parities will be assigned to some of the levels.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Evidence of tensor interactions in ^{16}O observed via (p,d) reaction

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The tensor interactions which originates from the pion exchange are essential interactions that provide the most significant two-body attraction in nuclear interactions. The tensor interactions induce nucleons with high momenta [1] through the D-wave component. The neccessity to include the tensor interactions in theoretical calculations to reproduce the quadrupole moment of the deuteron [2] as well as to explain the binding energies of the deuteron and alpha particles [3] provides decisive evidences on the importance of the tensor interactions. For heavier nuclei, recent ab-initio calculations [4] on light nuclei also show essential importance of the tensor interactions for binding nuclei up to mass number $A = 12$. Results from recent experiments with radioactive-isotope beams [5] and the subsequent theoretical studies [6] have also hinted at a possible important role of the tensor interactions in the changes of the magic numbers and the orders of single-particle orbitals in neutron-rich nuclei. However, despite the generally accepted fact that the tensor interactions play a dominant role in nuclei, no clear experimental evidence has been reported for nuclei heavier than the alpha particles.

In this talk, we report ^{16}O(p,d) reaction measurements using 198-, 295- and 392-MeV proton beams at RCNP, Osaka University to search for a direct evidence on an effect of the tensor interactions in light nucleus. Differential cross sections of the one-neutron transfer reaction populating the ground states and several low-lying excited states in ^{15}O were measured. Comparing the ratios of the cross sections for the $5/2^+$ (and/or $1/2^+$) excited state(s) and the $3/2^-$ excited state to the one for the ground $1/2^-$ state over a wide range of momentum transfer, we found a marked enhancement of the ratio for the positive-parity state(s). This observation is consistent with large components of high-momentum neutrons in the initial ground-state configurations explainable by the tensor interactions. We will discuss in detail how we come to this conclusion.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Neutron single-particle energies near ^{78}Ni: low-lying states in ^{79}Zn studied via single-nucleon transfer

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Single-particle properties of nuclei neighbouring shell closures constitute one of the most sensitive tests of our understanding of nuclear structure. Especially away from the line of beta stability, the properties and excitations of exotic isotopes provide essential data to refine the current models and interactions, as well as to assess their predictive power. The region of nuclei near ^{78}Ni, the doubly-magic nucleus with the largest N/Z ratio, is the focus of considerable experimental and theoretical interest. To date, scarce or no information is available on ^{78}Ni or any of its immediate neighbours. Whether ^{78}Ni can be considered a doubly-magic spherical nucleus depends on the size of the Z=28 and N=50 shell gaps and the amount of deformation-driving correlations, and contrasting predictions have been proposed [1][2].

^{79}Zn is the even-Z, N=49 isotone lying closest to ^{78}Ni. Low-lying excited states in ^{79}Zn were populated at REX-Isolde via the ^{78}Zn(d,p) reaction at 2.83 MeV/u, in inverse kinematics. This reaction yields important information about the N=50 shell gap, since the neutron can be transferred to orbits lying both below and above the gap. The coincident detection of charged particles and gamma rays, permitted by the coupling of the T-REX and Miniball arrays, was of paramount importance for the interpretation of the observed states, most of them populated for the first time. Results on ^{79}Zn level scheme and their implications on the size of the N=50 gap will be presented.

*** This work was supported by the European Union Seventh Framework Programme through ENSAR, contract no. 262010, by the project MEC Consolider - Ingenio 2010; CDS2007-00042 and by the European Commission through the Marie Curie Actions call FP7-PEOPLE-2011-IEF under Contract No. 300096.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Beta Decay of Exotic T_Z = -1, -2 Nuclei: the Interesting Case of ^{56}Zn

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Beta decay is a powerful tool to investigate the structure of nuclei far from the line of β-stability, giving direct access to the absolute value of the Gamow-Teller transition strength *B*(GT). However the finite Q_β value only allows access to states at low excitation energy.

On the other hand, Charge Exchange (CE) studies, at intermediate beam energies and zero momentum transfer, allow the determination of relative *B*(GT) values up to high excitation energy. Thus beta decay and CE reactions complement each other [1].

Under the assumption of isospin symmetry, the beta decay of proton-rich nuclei and CE reactions carried out on the mirror stable nuclei can be combined to determine the absolute *B*(GT) strength up to high excitation energies. Absolute *B*(GT) values can be determined even for GT transitions starting from extremely unstable nuclei if the beta-decay half-life and the Q_β value are precisely known. This "merged analysis" [1] method has been successfully employed in a series of experiments involving proton-rich nuclei in the *fp*-shell having T_Z = -1 [1, 2].

These results have instigated further investigations on more exotic nuclei above the *fp*-shell and the study of the T_Z = -2 case. The half-lives of the T_Z = -2, ^{56}Zn isotope and other nuclei with T_Z = -1 and -2 were measured in a beta-decay experiment performed at the LISE3 facility of GANIL. The fragmentation of a 74.5 MeV/u ^{58}Ni^{26+} primary beam on a natural Ni target was used for the ion production. The β^--type mirror CE reaction on the T_Z = +2, ^{56}Fe target nucleus was carried out at RCNP Osaka [1] using the (^{3}He,*t*) reaction at 140 MeV/u and $\vartheta = 0°$.

The decays of T_Z = -1 and T_Z = -2 proton-rich nuclei in the *fp*-shell show some important differences. Essentially only beta-delayed gamma emission is observed for T_Z = -1 nuclei. The decay of the T_Z = -2 nuclei is more complex because both beta-delayed gamma rays and beta-delayed proton emission are present, due to the extremely low proton separation energy. In particular, ^{56}Zn is a very interesting case. The decay mainly proceeds by proton emission, but gamma emission was also detected. Moreover, an exotic and perhaps unique feature was observed, namely a beta-delayed gamma-proton decay. The ^{56}Zn results are compared with the results of the mirror process, the CE ^{56}Fe(^{3}He,*t*)^{56}Co reaction.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Probing the neutron skin thickness in collective modes of excitation

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Collective motion in neutron-rich nuclei provides important information on the underlying structures evolving due to asymmetry in the proton-to-neutron number [1,2]. Theoretical frameworks based on nuclear energy density functional enable microscopic fully self-consistent description of nuclear excitation response, which in conjunction with recent experimental data on pygmy dipole strength, dipole polarizability, quadrupole excitations, etc., provides valuable insight into the size of the neutron skin thickness ΔR_{np} [3-6]. This quantity is directly connected to the properties of nuclear equation of state, i.e. the symmetry energy that is of paramount interest for nuclear structure, nuclear reactions and astrophysics. Covariance analysis in connection to the energy density functionals allow discerning relevant correlations between response properties in finite nuclei, properties in symmetric nuclear matter and neutron skin thicknesses. Of particular interest are correlations between the observables related to excitation phenomena in finite nuclei and the symmetry energy at saturation density (J), slope of the symmetry energy (L), and ΔR_{np}. Recently the relativistic nuclear energy density functional has been employed in a number of studies with the aim to determine in a unified way ΔR_{np}, J, and L from nuclear modes of excitation. Model calculations are realized in terms of the self-consistent random phase approximation, based on effective interactions with density dependent meson-nucleon couplings. In the study of isovector and isoscalar dipole response in ^{68}Ni, ^{132}Sn, and ^{208}Pb [3], the evolution of low-energy pygmy dipole strength (PDS) has been analyzed as a function of the density-dependence of the symmetry energy for a set of relativistic effective interactions. The occurrence of PDS is predicted in the response to both the isovector and isoscalar dipole operators, and its strength is enhanced with the increase of the symmetry energy at saturation and the slope of the symmetry energy. Charge-exchange excitations in neutron-rich nuclei provide another feasible approach to constrain ΔR_{np}, J, and L. Recent study showed that the excitation energies of the anti-analog giant dipole resonance (AGDR), obtained using a set of density-dependent effective interactions which span a range of the symmetry energy at saturation density, supplemented with the experimental values, provide a stringent constraint on value of the neutron skin thickness [6]. Therefore, a measurement of the excitation energy of the AGDR in (p, n) reactions using rare-isotope beams in inverse kinematics, provides a valuable method for the determination of neutron-skin thickness in exotic nuclei [6].

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Identification of intruder $\pi i_{13/2}$ state in ^{197}Tl

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The intruder $\pi h_{9/2}$ and $\pi i_{13/2}$ orbitals play important roles for the high spin states in the odd mass Thallium nuclei. In the lighter odd-A Tl nuclei, rotational bands built on these configurations have been observed, signifying the shape driving effect of these intruder orbitals. Although, a rotational band based on the $\pi h_{9/2}$ intruder state has been reported for ^{197}Tl [1], the intruder $\pi i_{13/2}$ state was not identified, so far, in this nucleus. In order to investigate the $\pi i_{13/2}$ state and the associated high spin states in ^{197}Tl, the γ-ray spectroscopy of ^{197}Tl was performed by populating the high spin states in this nucleus by a fusion evaporation reaction ^{197}Au(^{4}He,4n)^{197}Tl at 48 MeV of α-beam obtained from the K130 cyclotron at VECC, Kolkata. The γ-rays were detected using a clover HPGe detector, one LEPS (low energy photon spectrometer) and a large volume (80%) single crystal HPGe detector. A multiplicity array consisted of 50 BaF_2 detectors was also used. The DCO ratio measurement and the polarization asymmetry measurement, which could be possible because of the use of clover HPGe detector, were used to assign the spin and the parity of the levels. A new level scheme with firmly assigned spin and parity of the levels has been proposed from the present work. A $13/2^{+}$ state at an excitation energy of 1.5 MeV has been assigned to be the intruder $\pi i_{13/2}$ state in ^{197}Tl. However, no band structure on this state has been identified. A comparison of the excitation energy of this $\pi i_{13/2}$ state in the odd-A Tl (Z = 81) and Bi (Z = 83) nuclei are shown in Figure 1 for comparison. It may be noted that the excitation energy of this state increases and hence become more and more non-yrast with the increase in neutron number. This state has been observed until the neutron shell closure at N = 126 for Bismuth isotopes but ^{197}Tl (N = 116) is the heaviest Thallium isotope for which this state is observed. The configuration constrained total Routhian surface (TRS) calculations show a much smaller deformation for ^{197}Tl in $\pi i_{13/2}$ configuration than in $\pi h_{9/2}$ configuration. The excitation energy of the $\pi i_{13/2}$ state obtained from such calculations agrees well with the observed value. The details of the experiment, results and the interpretation of the level scheme will be presented.

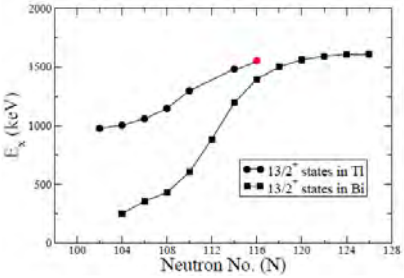

Figure 1: *Systematic of the excitation energy of the* $\pi i_{13/2}$ *states in odd-A Tl and Bi isotopes*.

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Non-adiabatic description of proton emission from the odd-odd nucleus ^{130}Eu

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Proton emission studies serve as an important tool to understand the structure of the proton rich nuclei near the drip-line [1]. We study doubly odd nuclei in this region using two quasiparticle plus rotor model [2], within the mean field of Wood-Saxon potential by introducing the non-adiabatic effects and the residual proton-neutron interaction. Proton emission half-lives which are sensitive to the single-particle proton states are obtained from the overlap of initial state (parent nucleus) and final state (daughter nucleus coupled with the emitted proton) wavefunctions. In the present work, we justify our formalism by explaining several features of ^{180}Ta and then discuss the role of Coriolis and residual proton-neutron interactions on the half-lives of ^{130}Eu [3]. We show that only a particular combination of spin and parity ($J^{\pi} = 1^{+}$) could explain the experimental half-life and hence can be unambiguously assigned as the proton emitting state. We also discuss the interdependence of the Coriolis and the residual proton-neutron interactions.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

New structure information on ^{81}Ga from the β^- decay of ^{81}Zn

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We report on the results of the β-decay of ^{81}Zn. The experiment was performed at the CERN ISOLDE facility in October 2011, in the framework of a systematic ultra-fast timing [1] investigation of neutron rich nuclei populated in the decay of *Zn*. Almost pure beams of *Zn* ions were delivered to our fast-timing station thanks to the use of the ISOLDE RILIS and a cooled quartz transfer line. This allowed the study of beta decay of *Zn* isotopes ranging from $A = 71$ to $A = 82$.

The analysis included beta-gated gamma ray singles and gamma-gamma coincidences from the decay of ^{81}Zn. The new level scheme of ^{81}Ga includes more than 50 new transitions and about 40 new levels in the energy range up to 6.4 MeV, which extends significantly the previously known structure [2]. The intensities and spin-parity assignments will be discussed together with the preliminary analysis of the level lifetimes obtained using the fast-timing technique.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Surface Deformations of Weakly-Bound Nuclei in the Continuum

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In exploring the existence limits of nuclear systems, exotic phenomena such as halos and associated soft mode excitations are expected towards the particle drip lines. A crucial issue for the theoretical descriptions of drip-line nuclei is to be able to self-consistently treat the continuum effects, deformations and spatial extended structures. For medium-mass and heavier nuclei, the theoretical tool of choice is the Hartree-Fock-Bogoliubov theory. However, for deformed nuclei in the continuum, one has to resort to the coordinate-space HFB approach [1], which is very expensive. To this end, we implemented the hybrid parallel calculations to employ a large box for describing weakly-bound deformed nuclei [2]. These calculations were performed in the China's top supercomputer Tianhe-1A. As a reward, a new exotic deformed halo structure has been found and new insights into the halo mechanisms in terms of quasiparticle resonances are obtained [3]. In ^{38}Ne, calculations found an exotic "egg"-like structure consisting of a spherical core plus a prolate halo, for which the resonant continuum plays an essential role. This is a manifestation of completely core-halo deformation decoupling. Generally the halo probability and the decoupling effect in heavy nuclei are reduced compared to light nuclei, due to denser level densities around Fermi surfaces. However, deformed halos in medium-mass nuclei are possible with sparse levels of negative parity, for example, in ^{110}Ge. This can be understood that the condition of halo occurrence is associated with the phase space decoupling near the Fermi surface. The obtained large isovector deformations in deformed halos imply unusual isovector quardpole modes and further experimental observations will be very interesting. The surface deformations of pairing density distributions are also influenced by the decoupling effect and are sensitive to the effective pairing Hamiltonian, for which the pair transfer experiments are expected to give important constraints on theories.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Microscopic mean field approximation and beyond with the Gogny force

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Many theoretical models have been developed to describe nuclear structure. Among them, a crucial role is played by the mean field based models using effective forces which allow to solve at the same time many body and nuclear interaction problems. Here we present a review of several works including D1S Gogny interaction in mean field approaches and beyond, leading to a better understanding of nuclear structure phenomena and pointing out the limitations of the models themselves. This allows a rigorous analysis of strong and weak points of the assumptions made in theoretical approaches.

Starting from the pure HFB description and extenting it to the five dimension collective Hamiltonian (5DCH) we will discuss the evolution of shell closures : vanishing for N=20,28 [1], appearance for N=16 [2] and the existence of N=40 [3]. We will point out that some data cannot be reproduced within the 5DCH model, which implies the need of a formalism able to simultaneously describe high and low energy spectroscopy as well as collective and individual excitations. Then we will present the RPA formalism and the study of giant resonances in doubly magic, spherical, exotic nuclei [4]. After exposing the QRPA approach in axially symmetric deformed nuclei and the role of the intrinsic deformation in giant resonances [5], we will discuss the appearance of low energy dipole resonances for light nuclei [6]. The isoscalar or isovector as well as the collective or individual nature of pygmy states will be debated. As a feasibility example, we present the first microscopic fully coherent description of the multipole spectrum of heavy deformed nucleus ^{238}U [7].

In this context, the comparison of the low energy spectroscopy obtained with these two extensions of static mean field is done for several nuclei especially for 2^+ and 0^+ states. This comparison leads to perspectives for evolution of our models to bridge the gap between QRPA and 5DCH approaches.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Low-lying bands with different quadrupole deformation in ^{155}Dy

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To investigate the interplay between collective and single particle degrees of freedom in odd nuclei, Recoil distance Doppler-shift and Doppler-shift attenuation lifetime measurements were carried out for levels in ^{155}Dy in coincidence mode. The nucleus ^{155}Dy is positioned in mass region A~150, which is characterized by a rapid shape transition and its level scheme is well known [1,2]. The main goal of the present work was to measure electromagnetic transition strengths, intermediate and high spins in the different bands observed and the second aim was to perform particle plus Triaxial rotor model (PTRM) calculations to compare the experimental level scheme and transition strengths with theoretical ones in order to get information on the quadrupole deformation (ε, γ) of the bands studied.

The experiments were performed at the Laboratori Nazionali di Legnaro with the multidetector array GASP using the reaction ^{124}Sn(^{36}S,5n). For the RDDS experiment the target and stopper foils were mounted in the Cologne coincidence plunger [3]. Data were taken at 23 target-to-stopper distances. For the analysis of RDDS data, the gate is setting from above, on the shifted component of a transition directly feeding the level of interest. 26 lifetimes, most of them for the first time, were determined using the Differential decay curve method [4] for the analysis of the data. 18 of them have been determined using RDDS and 10 lifetimes have been determined using DSAM data. The results show that at low and medium spins, Particle plus Triaxial rotor calculations reveal different quadrupole deformations for the one-quasineutron bands in the transitional nucleus. At high spin, the reduced B(E2) transition probabilities do not show a significant decrease till the higher investigated levels.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Exotic rotations and seniority isomers in Nd nuclei

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The existence of triaxial nuclei has been the subject of a long standing debate. The possibility of soft and rigid triaxiality has been proposed very early, and many theoretical and experimental studies have been devoted to this intriguing phenomenon since then. More recently two unique fingerprints of triaxiality in nuclei have been intensively studied: the wobbling motion [1] and the dynamic chirality [2]. These exotic types of motion were observed in specific regions of the nuclear chart: the wobbling motion in the odd-even Lu nuclei with $A \sim 160$ [3], the chirality primarily in the odd-odd and odd-even nuclei with $A \sim 130$ nuclei [4,5]. We have recently studied the Nd nuclei up to very high spins and identified several bands, which were interpreted as the manifestation of various types of collective motion: tilted axis rotation, principal axis rotation along the short and long axes, wobbling motion, chiral bands[6]. Another phenomenon revealed by our recent results on the Nd nuclei with neutron numbers just below the N=82 shell closure, is the shape coexistence. It is induced by the existence of some high-spin seniority isomers which are built on a spherical shape and are surrounded by triaxial bands. The shape coexistence phenomenon is well described by Cranked Nilsson Strutinsky calculations. All these types of excitation and their interpretation will be discussed and exemplified with recent results obtained on Nd nuclei.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Combining γ and particle spectroscopy in Cologne

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To gain additional information on nuclear structure from particle-induced reactions, the new silicon detector array SONIC consisting of up to eight ΔE-E-telescopes was installed inside the existing HPGe-detector array HORUS in Cologne. Because of the good energy resolution of the silicon detectors, light ejectiles (p, d, t, and α) can be easily distinguished. The main purpose of this detector array will be the study of inelastic scattering using p, d and α beams delivered by a 10 MV Tandem accelerator. Two test experiments have already been performed. Gating on the excitation energy of a specific level in a ^{140}Ce(p,p'γ) experiment improved the peak-to-background ratio in the γ-ray spectrum and gave access to additional nuclear structure information. In ^{172}Yb(d,$X\gamma$), where X=p, d', or t, clear discrimination of the ejectiles was achieved. The results of these first test experiments will be presented as well as future improvements of the setup and upcoming experiments.

Supported by the DFG (ZI 510/4-2). S.G. P., V. D., A. H., J. M., A. S., P. S., and M. S. are members of the Bonn-Cologne Graduate School of Physics and Astronomy.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

On the Road to FAIR: First Operation of AGATA in PreSPEC at GSI

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The international Facility for Antiproton and Ion Research (FAIR) which is currently under construction at Darmstadt, Germany, will provide intense relativistic beams of exotic nuclei at its Superconducting-FRagment Separator (Super-FRS). The planned HISPEC experiment foresees as core instrument the European Advanced GAmma-ray Tracking Array (AGATA) [1]. AGATA is a highly segmented array of HPGe-detectors suitable for in-beam γ-ray spectroscopy of relativistic ions at highest possible energy resolution and sensitivity. About 20 AGATA detector modules – individually encapsulated 36-fold segmented HPGe crystals – have been used at GSI's FRagment Separator (FRS) in the framework of the PreSPEC-AGATA campaign, the predecessor of the future HISPEC experiment at FAIR. Reaction products have been characterized using the Lund-York-Cologne CAlorimeter (LYCCA) [2]. Effectively some five weeks of primary beam time have been made available in the year of 2012 for commissioning the set-up and start of the experimental programme.

The commissioning of the PreSPEC-AGATA campaign was done using Coulomb excitation reactions of a primary beam of ^{80}Kr ions at energies of 150 MeV per nucleon on a 400 mg/cm^2 thick secondary gold target. The 615-keV γ-ray line from the decays of the Coulomb-excited first 2^+ states of ^{80}Kr was observed with an energy resolution of 2.5% at the current stage of the data analysis before application of γ-ray tracking techniques. Further experiments made use of relativistic secondary beams of unstable neutron-rich nuclei or isomers produced either by target-induced fission of a relativistic uranium beam or in primary fragmentation reactions. The experiments combine the development of dedicated FAIR-relevant tools for high-resolution in-beam spectroscopy of relativistic radioactive ion beams with timely questions of nuclear structure research, such as Coulomb-excitation of a band-terminating isomer of ^{52}Fe, low-lying E1 modes of neutron-rich ^{64}Fe, evolution of nuclear shapes of heavy Zr isotopes, or the collectivity of neutron-rich isotopes near ^{208}Pb.

We report on the initial performance of the experimental set-up of the PreSPEC-AGATA campaign for in-beam γ-ray spectroscopy experiments with relativistic beams, discuss the experiments that were carried out, highlight preliminary results from them, and give an outlook to the continuation of the experimental campaign coming up later this year.

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Isomers in heavy nuclei: structure and projectile fragmentation studies

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Fragmentation reaction proved to be a powerful tool in the study of neutron-rich nuclei. Using internal isomeric decay spectroscopy a large amount of experimental information was obtained on heavy neutron-rich nuclei in the Hf-Hg region during the last decade. This region is characterised by the presence of nuclei with different shapes in their ground-states, such as prolate, oblate, triaxial and spherical. Shape transitional nuclei are difficult to treat theoretically, consequently this region is considered to be a crucial testing ground for nuclear models. The exact place where the shape transition is predicted depends on the details of the theoretical calculations The prolate-oblate transitional region was reached experimentally for (Z=76) Os and Ir (Z=77), as proved by the observation of oblate isomeric states in 197,198,199Os and 201Ir [1]. For Ta (Z=73) and W (Z=74) isotopes no clear evidence of oblate deformation exists so far, with 192W and 189Ta being the most neutron-rich isotopes with spectroscopic information.

Studying the population of isomeric states information about the fragmentation reaction process can be obtained. Experimentally we cannot determine the population of a single state with a given angular momentum, but only the total population of all the states decaying into a long-lived isomeric state. Therefore, the study of the population at high angular momentum provides a much more stringent test of the theory than populations at lower angular momenta. Recently, new experimental results were obtained on a large number of high-spin states (with spins up to 55/2 hbar) in nuclei in the vicinity of the N=126 line, from the fragmentation of ^{238}U [2,3]. The population of these states is larger than expected from existing theoretical calculations, with implications on the feasibility of different experiments requiring isomeric beams.

The talk will discuss both nuclear structure results and population of isomeric states in the fragmentation reaction.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

The three shapes of ^{32}Mg

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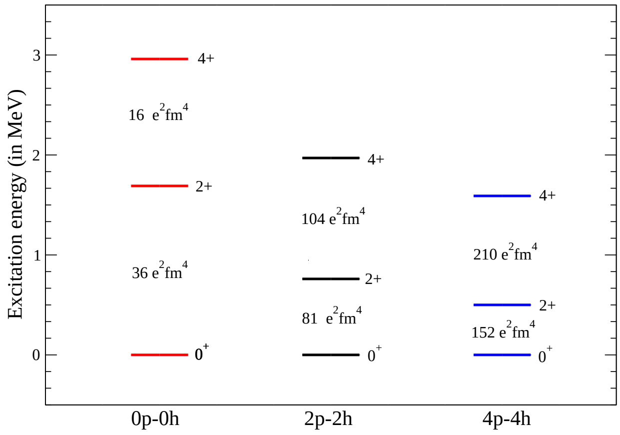
What is the driving force behind the abrupt changes leading to the appearance of the ”islands of inversion”? What makes these intruder states so special? That they need to be highly correlated in order to compensate for the energy loss associated to the breaking of the normal filling of the spherical mean field. Obviously, small gaps are easier to overcome, thus a reduction of the neutron magic gaps at the very neutron rich edge is good news for the intruders. Let us concentrate in the N=20 case. Compared to the configurations with closed N=20, the intruders (np-nh) have neutrons in open sd and pf-shell orbits and in some cases protons in open sd- shell orbits. This activates the neutron-proton quadrupole interaction, which can build up correlations very efficiently if the open orbits are the appropriate ones. And whose are those is dictated by the different SU(3) variants. To get large coherence the neutrons and the protons must be in one or another of these schemes. In the N=20 intruders, the neutrons in the orbits 0f$_{7/2}$ and 1p$_{3/2}$, and the protons in 0d$_{5/2}$ and 1s$_{1/2}$ are in the Quasi-SU(3) regime and the neutrons in 0d$_{3/2}$ and 1s$_{1/2}$ in Pseudo-SU3.



These statements can be made quantitative, for instance in the case of ^{32}Mg. We first do calculations at fixed N$\hbar\omega$. The results are presented in the figure. We found the semimagic 0p-0h result, with a high excited 2$^+$ and a low B(E2); the rotational-like 2p-2h whose B(E2) corresponds to β=0.3 and finally the perfect rigid rotor 4p-4h with E(4$^+$)/ E(2$^+$)=3.2 and a huge B(E2) that corresponds to a super-deformed structure. A crucial issue is that the gains in energy due to the correlations are very different in the 0p-0h, 2p-2h and 4p-4h spaces; 1.5 MeV, 12.5 MeV and 21 MeV respectively. These huge correlation energies may eventually overcome the spherical mean field gaps. In fact this is the case in ^{32}Mg. With the effective interaction sdpf-u-mix, the lowest 2p-2h 0$^+$ state is degenerate with the lowest 0$^+$ of the 4p-4h space and both are 1 MeV below the 0$^+$ of the 0p-0h configuration. We will show that in the fully mixed calculation the three states are necessary to understand the ground state band and the extremely low excited 0$^+$ state recently found at Isolde.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Nuclear structure study of ^{106}Pd and ^{106}Cd with the (n,n$'\gamma$) reaction

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Quadrupole shape vibrations are considered to be a fundamental degree of freedom of nuclei. Several candidates in the $_{48}$Cd and $_{46}$Pd region have been proposed as examples of good quadrupole shape vibrators; however, in recent studies of ^{112,114,116}Cd [1,2,3] and ^{106,108,110}Pd [4] , serious discrepancies from the vibrational decay pattern were found, suggesting a breakdown of the quadrupole vibrational picture. It has been suggested that these nuclei are more closer to a γ-soft rotor [5] rather than a vibrator. Although this interpretation remains open, it is expected that studies of the $_{48}$Cd and $_{46}$Pd isotopes will bring new insights into their structure, and will clarify the limitations of the quadrupole vibrational model in nuclear structure.

The low-lying states of ^{106}Pd and ^{106}Cd have been studied with the (n,n$'\gamma$) reaction at the University of Kentucky 7 MV Van de Graaff accelerator facility. Inelastic neutron scattering is a very powerful tool to study nuclei due to its non-exclusive character that allows the observation of non-yrast states, which may not be observed in other types of reactions. Excitation functions with neutrons of energies *(E_n)* from 2.0 to 3.8 MeV in 0.1-MeV steps, angular distributions measurements with E_n=2.2, 2.7 and 3.5 MeV, and γ-γ coincidence data at E_n=3.3 MeV were used to characterize the decay of the excited states in ^{106}Pd. In addition, excitation functions with E_n from 2.5 to 4.0 MeV and angular distributions with E_n= 2.6, 3.3 and 3.7 MeV were employed to investigate for the levels in ^{106}Cd. Lifetimes were also measured by the Doppler-shift attenuation method (DSAM) for both nuclei. The detailed structure of these isobaric nuclei will be presented.

This material is based upon work supported by the U.S. National Science Foundation under Grant No. PHY-0956310.

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Normal and Superdeformed Band Structures of ^{105}Ag

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The band structures of ^{105}Ag have been studied by us using self-consistent deformed Hartree-Fock and angular momentum projection procedures[1]. We have used large enough shell model spaces (two major shells each for protons and neutrons), so that there is scope for large deformations in the model space. Surface delta interaction is used as the residual interaction among the active nucleons. The normal as well as the superdeformed bands of ^{105}Ag are fairly well described in the HF and angular momentum projection calculations. To obtain the superdeformed configurations, quadrupole constraints are used in the Hartree-Fock calculation to drive the nucleus to larger deformations, leading to occupation of large j and small m orbits which are prolate deformation-driving. Angular momentum projections are also done from the superdeformed configurations obtained by the constrained HF procedure. High nspins upto J = 71/2 are obtained for one of the superdeformed configurations and the spectrum matches quite well with the spectrum of the superdeformed band known experimentally [2]. There is considerable signature-splitting in the superdeformed spectrum obtained in our angular mentum projection calculation. Besides the energy spectra of normal and superdeformed bands, we have studied the electromagnetic trnsitions and the e-m moments in the deformed HF and J projection model. The spectrum for the positive parity normal deformed band is shown in the Figure.

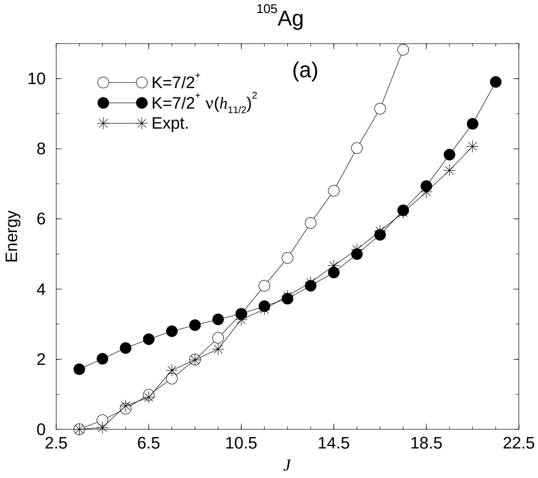

Figure 1: *Energy spectrum for the normal deformed +ve parity band of* ^{105}Ag. *Experimental spectrum is from Ref [2].*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Microscopic approach to the structure of superheavy nuclei

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A fully microscopic theoretical framework based on nuclear relativistic energy density functionals (REDFs) [1] is applied to studies of shape evolution, excitation spectra and decay properties of superheavy nuclei. On the self-consistent mean-field level the microscopic approach is used in the description of rapid shape transitions, from spherical to axial and triaxial, in alpha-decay chains of superheavy nuclei [2,3]. The occurrence of a deformed shell gap at neutron number N=162, and its role on the stability of nuclei in the region around Z=108 is investigated. Predictions for long-lived high-K isomeric states are compared with very recent data in the decay chain of ^{270}Ds [4].

An especially interesting feature in the region of heavy and superheavy elements is the possible occurrence of shape-phase transitions and critical-point phenomena. A collective Hamiltonian model [5], based on microscopic REDFs is employed in studies of shape coexistence phenomena, complex excitation patterns and electromagnetic transition rates associated in Hs isotopes with the evolution of shell structures. Microscopic signatures of ground-state shape phase transitions are analyzed [4] using excitation spectra and collective wave functions obtained by diagonalization of a quadrupole collective Hamiltonian, with parameters fully determined by microscopic self-consistent mean-field calculations for triaxial shapes.

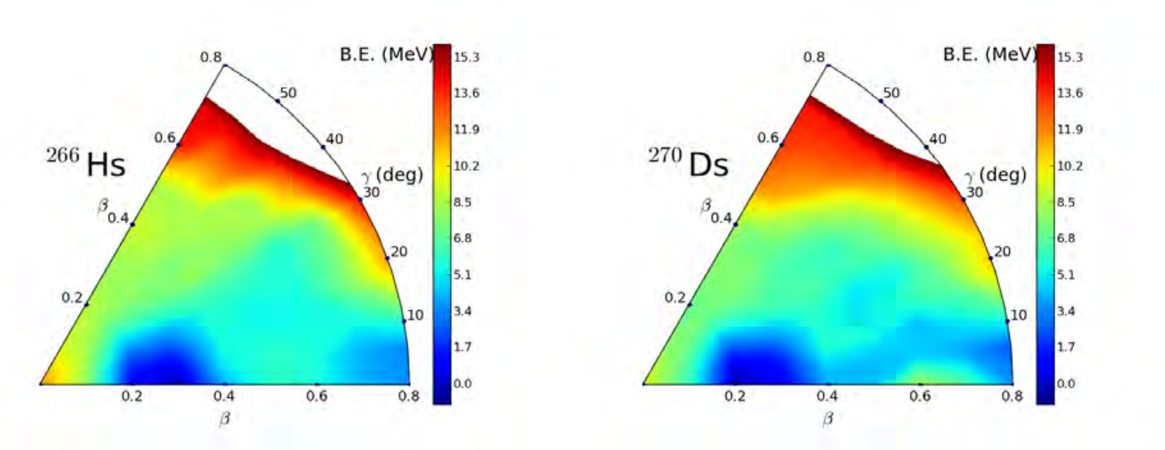

Figure 1: *Triaxial energy maps of* ^{266}*Hs and* ^{270}*Ds.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

The structure of nuclei around 100Sn: A simple shell model description

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Identical particles come in two varieties: bosons and fermions. The wave function for a system of identical fermions must be anti-symmetric. It can be expressed as the tensor product of single-particle states, where the seniority coupling scheme turns out to be a very useful concept. It is associated with a large variety of phenomena including nuclear pairing, superconductivity, magnetism and quantum chemistry.

In this talk I will address a few issues regarding the seniority structure of nuclei around 100Sn. In particular, I will show that the seniority symmetry is dynamically conserved in j=9/2 shells irrespective of type of interaction. This may be a unique phenomenon for nuclear physics, which is characterised by large spin-orbit coupling. The collectivity in Sn isotopes may be enhanced by the mutual effect of seniority and pesudospin symmetry.

I will also briefly comment on the shell structure of drip line nuclei from a simple single-particle point of view and its indication on the pseudospin symmetry in nuclei around 100Sn.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Nuclear structure of the heavy iron isotopes in the vicinity of ^{68}Ni

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The region around Z=28 and N=40 became of particular interest since the observation, that the 2^+ energy in ^{68}Ni rises to above 2 MeV [1], as a result of the sub-shell gap separating the pf and $g_{9/2}$ orbitals and the discovery of a 0^+ as its first excited state [2]. Using excitation level schemes, electromagnetic transition strengths, spectroscopic factors and nuclear moments, effective residual interactions have been established, which explain to a reasonable extent the nuclear structure in the Z≥28 region. Below Z=28 an onset of deformation has been observed in the cobalt [3], iron [4] and chromium [5,6] isotopes near N=40. The tensor interaction [7] between neutrons in the $\nu g_{9/2}$ orbital and protons in the $\pi f_{7/2}$ orbital causes the N=40 gap to shrink with decreasing proton number, enhancing collectivity. Shell model calculations in the $\pi(f_{7/2}, p_{3/2}, f_{5/2}, p_{1/2})$ and $\nu(p_{3/2}, f_{5/2}, p_{1/2}, g_{9/2}, d_{5/2})$ model space are currently possible. Nevertheless, the onset of deformation, below Z=28, is not fully comprehended, due to lack of proper effective interactions in this region.

This work reports on a β-decay study of the neutron-rich $^{58,60-68}$Mn isotopes. The isotopes were produced at the ISOLDE facility (CERN, Geneva, Switzerland) in a proton-induced fission of ^{238}U and selected using resonant laser ionization combined with mass separation. After implantation on the movable LISOL tape system, the subsequent β and γ radiation was registered by three plastic ΔE scintillators and two MINIBALL detector clusters, respectively [8].

The latest results concerning $T_{1/2}$ and P_n values of the $^{58,60-68}$Mn β-decays and the nuclear structure of the corresponding Fe and Co isotopes, will be presented, including a newly observed, isomeric state in ^{63}Fe. $^{65-67}$Co isotopes were previously studied in the $^{65-67}$Fe β decay at the LISOL facility [9,3] in Louvain-La-Neuve, but the much higher statistics in the Mn β-decay data allows to establish more detailed Co level schemes. The level schemes of both Fe and Co isotopes will constitute an important benchmark for establishing proper effective interactions in the ^{68}Ni region.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Application of the sextic oscillator potential together with Mathieu and spheroidal functions for triaxial and X(5) type nuclei

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The Bohr-Mottelson Hamiltonian [1,2] is amended with a potential which depends on both β and γ deformation variables and which allows us to separate the β variable from the γ variable and the three Euler angles Ω, which are still coupled due to the rotational term. Further, by performing a second order expansion of the rotational term around $\gamma_0 = 0$ and $\gamma_0 = \pi/6$ for X(5) type nuclei and triaxial nuclei respectively, and then averaging the resulting terms with specific Wigner functions, a complete separation of variables is achieved. The expansion is done such that the periodicity of the γ Hamiltonian to be preserved. A sextic oscillator with centrifugal barrier potential is considered for the β equation, in order to realistically describe the experimental data of the well deformed nuclei. The Schrödinger equation for the β variable is quasi-exactly solved. Concerning the γ equation, its solution depends on the nature of the considered nuclei. Indeed, for the X(5) like nuclei, choosing a periodic potential which has a minimum in $\gamma_0 = 0$, the solutions are the angular spheroidal functions. On the other hand for triaxial nuclei, a periodic potential exhibiting a minimum in $\gamma_0 = \pi/6$ is considered and finally the equation in γ is reduced to a Mathieu equation. The models developed in this way are conventionally called the Sextic and Spheroidal Approach (SSA) [3] and the Sextic and Mathieu Approach (SMA) [4]. Both approaches use an anharmonic transition operator to calculate the reduced E2 transition probabilities. In Refs. [4,5,6], the SMA was successfully applied for several nuclei, ^{188}Os, ^{190}Os, ^{192}Os, ^{228}Th, ^{230}Th, ^{180}Hf and ^{182}W, chosen according to a certain signature of the rigid triaxial rotor. In Ref. [3], a good agreement of the SSA results with experimental data of several X(5) candidate nuclei as ^{176}Os, ^{178}Os, ^{180}Os, ^{188}Os, ^{190}Os, ^{150}Nd, ^{170}W, ^{156}Dy, ^{166}Hf and ^{168}Hf, was obtained. A salient feature of our investigations consists of that the Mathieu and spheroidal functions are periodic, defined on bounded intervals and normalized to unity with the integration measure $|\sin 3\gamma| d\gamma$, preserving in this way the hermiticity of the initial γ Hamiltonian. As a final conclusion, SSA and SMA represent realistic tools for the description of X(5) candidate nuclei and of triaxial nuclei with equilibrium shapes close to $\gamma_0 = 0$ and $\gamma_0 = \pi/6$, respectively.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Terminating bands observed to new heights of spin and excitation energy.

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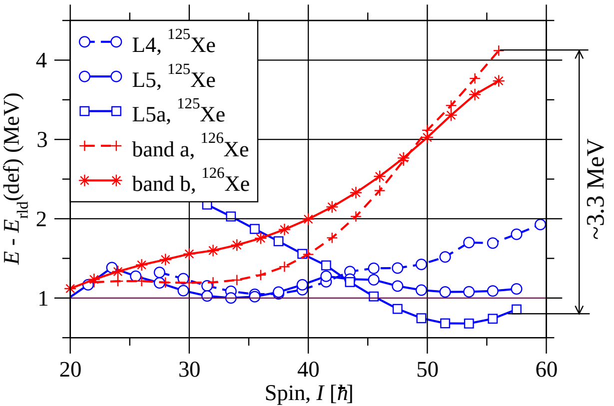
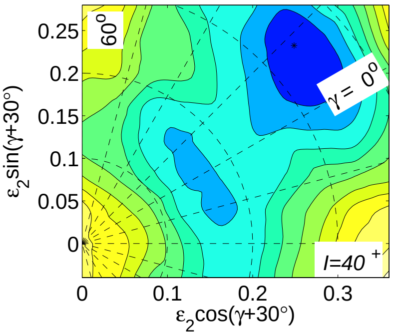


High-spin bands with known spin values and excitation energies have been observed in ^{125,126}Xe [1]. The bands in these two nuclei show interesting differences as seen clearly in the figure to the right where they are drawn relative to the standard rotating liquid drop reference [2]. Thus, for $I \approx 55$, the bands in ^{125}Xe are much lower in energy than those in ^{126}Xe. On the other hand, collective yrast bands in neighbouring nuclei should come at similar energies in an analogous manner as nuclear masses in deformed regions show small and regular variations as functions of Z or N when drawn relative to a liquid drop energy. Thus, the yrast bands in ^{126}Xe should be located at similar energies as the observed bands in ^{125}Xe, i.e. the observed bands in ^{126}Xe are 3-3.5 MeV above yrast at the highest observed spin value, $I = 56$. The high excitation energy of these states suggests that their configurations are very different from those of the yrast states.



Noting that collective bands in $Z = 50 - 54$ nuclei are generally formed with two $g_{9/2}$ proton holes in the $Z = 50$ core, we have carried out CNS calculations [2] and constructed potential energy surfaces with this constraint as exemplified here for $I = 40^+$. There are two minima in these surfaces; one with a deformation $\varepsilon = 0.30 - 0.35$ and another which moves towards smaller deformation coming higher in energy ($\Delta E \approx 0.9$ MeV for $I = 40$) when the spin increases. This minimum becomes very shallow for $I \approx 50$ and disappears at somewhat higher spin values suggesting some kind of termination close to $I = 60$. Our interpretation is then that the bands in ^{125}Xe are built in the more deformed minimum corresponding to configurations with neutrons excited across the $N = 82$ gap (similar to the interpretation for the bands in both ^{125}Xe and ^{126}Xe in [1]) while the bands in ^{126}Xe are built in the smaller deformation minimum corresponding to neutron configurations in the $N = 50 - 82$ valence space. Life times measurements [1] support that band L5a in ^{125}Xe should be assigned to the more deformed minimum but are at too low spin values to be decisive in ^{126}Xe. Note that $I = 56$ corresponds to the highest even spin values possible for valence space configurations as exemplified by the configuration (relative to $Z = 50$, $N = 64$) predicted for the $I = 56^+$ state:

$$\pi\left[(g_{9/2})_8^{-2}(g_{7/2}d_{5/2})_{10}^4(h_{11/2})_{10}^2\right]_{28}\nu\left[(g_{7/2}d_{5/2})_{8.5}^{-3}(h_{11/2})_{18}^6(d_{3/2}s_{1/2})_{1.5}^5\right]_{28}.$$

It is of special interest that these I_{max} states are observed although they are at a high excitation energy.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Direct evidence of ground state wave-function of neutron-rich ^{30}Na isotope through Coulomb Breakup

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'Island of Inversion' is a long cherished unsolved phenomena in nuclear structure physics since mid-70s. The pioneering work on $^{31-32}$Na [1] by C. Thibault et. al. clearly suggested the breakdown of conventional shell model around N~20. Several theoretical prediction and explanation have been done for those nuclei in this region. Specially one need to take into account various nucleonic interaction to explain and understand the observed exotic properties for those nuclei in this region. Few measurements [2,3] have been performed to study structure of ^{30}Na. But no measurement is available to probe the ground-state configuration directly. Assignment of spin and parity of ground state is still inconclusive. Coulomb breakup is sensitive to the valence nucleon wave-funtion of loosely bound nuclei [4]. It becomes a very efficient and sensitive tool particularly for those nucleon having wave-function with long tail. In our experiment, Radioactive Ion Beam of nuclei $^{29-31}$Na, $^{31-33}$Mg were populated through fragmentation of ^{40}Ar beam, impinging on ^{9}Be (8gm/cm^{2}) target with energy ~530MeV/u , delivered by the synchrotron SIS at GSI, Darmstadt in 2010 . After the Fragment Separator (FRS) the beam was tranported to cave C where all the complete kinematic measurements were performed after secondary reaction with lead (^{208}Pb) and carbon (^{12}C) target using LAND-FRS set up. Preliminary analysis suggests valence neutron occupation of "pf" orbital from the next shell in the ground state of 30Na. This is first direct evidence of failure of magic number below N~20 region.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Non-axial study of some even-even actinide nuclei with octupole-octupole interaction

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Study of octupole correlations in the actinides have attracted interest because of the predictions that octupole deformation would be present in the Z~88 and N ~ 134 region [1]. These predictions have been explored through a series of experimental studies, which have centered on energy spectra and transition properties [2,3]. A number of theoretical studies are dedicated over the years to the study of octupole degree of freedom in nuclei [2,4]. In the present work, the octupole-octupole interaction is incorporated to the pairing plus quadrupole-quadrupole model. The microscopic framework Cranked Hartree Bogoliubov [5] is employed with pairing plus quadrupole-quadrupole plus octupole-octupole interaction to study the yrast bands of some even-even actinide nuclei. The results are obtained for yrast energies, intrinsic quadrupole moments, octupole moments, deformation parameter, non-axiality parameter, occupation probabilities and B(E2) transition probabilities. From the comparison of the calculated energy levels and B(E2) transition probabilities, one can infer that the model with inclusion of octupole-octupole interaction appears to give a reasonable good description of the actinide nuclei. In addition, the non-zero values of calculated octupole moments confirm the non-axial octupole nature of these nuclei.

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Investigation of the E2 and E3 matrix elements in ^{200}Hg using inelastic scattering

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A nuclear structure campaign has been initiated investigating the isotopes of Mercury around mass 199. Currently ^{199}Hg provides the most stringent limit on an atomic electric dipole moment (EDM) [1]. The observation of a permanent EDM would represent a clear signal of CP violation from new physics beyond the Standard Model. The EDM of an atom is induced by the Schiff moment, the lowest order time-reversal odd moment of a nucleus that is measurable in a neutral atom [2]. Theoretical calculations for ^{199}Hg are very difficult and give varied predictions for the excited-state spectrum. Understanding the E2 and E3 strengths in ^{199}Hg will make it possible to develop a nuclear structure model for the Schiff strength based on these matrix elements and thereby constrain present models of the contribution of octupole collectivity to the Schiff moment of the nucleus.

The most direct way of measuring the matrix elements connecting the ground state to excited states is through inelastic hadron scattering. The high level density of a heavy odd-A nucleus like ^{199}Hg is extremely challenging. Fortunately, complementary information can be determined for states in the neighbouring even-even isotopes of ^{198}Hg and ^{200}Hg. Additionally, single-nucleon transfer reactions on targets of even-even isotopes of Mercury can yield important information on the single-particle nature of ^{199}Hg.

The work presented here comprises two experiments using a 22 MeV deuterium beam impinging on an isotopically enriched target of ^{200}Hg^{32}S. The first experiment is an inelastic deuteron scattering experiment, $^{200}\mathrm{Hg(d,d')}^{200}\mathrm{Hg}$, which consists of 20 angles ranging from 10° to 115° up to an excitation energy of $\sim$ 6 MeV. The second experiment is a single-nucleon transfer reaction into ^{199}Hg, $^{200}\mathrm{Hg(d,t)}^{199}\mathrm{Hg}$, and includes 10 angles from 5° to 50° up to an excitation energy of $\sim$ 3 MeV. These experiments were performed using the Q3D spectrograph at the Maier-Leibnitz Laboratory (MLL), a joint facility of Ludwig-Maximilians-Universität München (LMU) and the Technische Universität München (TUM). The Q3D spectrograph offers an unmatched energy resolution (typically $<$ 10 keV) for these types of experiments. Preliminary results from these experiments will be presented.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

The observation of a strong E0 component in the $2_2^+ \rightarrow 2_1^+$ transition in ^{184}Hg from the β-decay of laser-ionized thallium isotopes: a strong signature for shape coexistence.

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The mass region of neutron-deficient mercury and lead isotopes near the midshell (N=104) is well known for the phenomenon of shape coexistence. In neutron-deficient even-even $^{180-188}$Hg isotopes, an oblate (β_2~ -0.15) ground state band is found to coexist with an excited prolate (β_2~0.25) band at low spin and low-excitation energies. This band is built on top of a deformed excited 0^+ state, which is interpreted as resulting from proton excitations across the Z=82 closed shell. Such *intruder* states have been found to be a widely occurring structural feature of nuclei at and near closed shell.
The low-lying coexisting states in ^{180,182,184}Hg have been studied at ISOLDE, CERN through the β^+/EC decay of ^{180,182,184}Tl as part of a systematic α, β, and β-delayed fission study of neutron-deficient thallium isotopes [1]. The β^+/EC decay is a very simple but still powerful tool which allows to effectively populate low-lying not-yrast states in the daughter nucleus, normally not easily accessible with other techniques, thus providing complementary information to the ones from in-beam γ-spectroscopy studies [2] and from α-decay studies from the Pb parent nuclei [3].

Mass-separated Tl beams, produced at ISOLDE, CERN, in the bombardment of ^{238}U by 1.4 GeV protons and selectively laser ionized, were implanted on a carbon foil mounted on a rotating wheel. The implantation foil was surrounded by two Si detectors for α, β and electron detection while γ rays were detected with two high-resolution single-crystal Ge detectors.
By means of unambiguously Si-γ and γγ coincidences, a detailed level scheme of the coexisting states in Hg has been built-up as well as a detailed description of their decay properties (γ intensities, E0 component of $2^+ \rightarrow 2^+$ transitions). The newly observed or better energy-determined 0_2^+, 2_2^+, 2_3^+ states in ^{180,182}Hg follow well the general trend of the prolate band. They confirm that the minimum of the parabolic behavior in excitation energy of the prolate band occurs in ^{182}Hg, as expected. The exceptionally large E0 component observed in the $2_2^+ \rightarrow 2_1^+$ transition in ^{184}Hg (23±5) confirm that the two states are strongly mixed and they have different deformation.

Isomerism is well-known in the heavier thallium isotopes and the population of low-spin states as well as high-spin states (up to 8^+ in ^{182,184}Hg) in the β-decay points to similar features in the lighter thallium isotopes.
Thanks to the laser selective ionization, the decay properties of the three isomeric states (2^-, 7^+, and 10^-) in ^{184}Tl have been singled out.

The knowledge on the decay properties of these nuclei has been largely improved by this study. The information gathered can be combined with the ones obtained with different techniques, such as in-beam γ and conversion-electron spectroscopy, Coulomb excitation on post-accelerated radioactive ions (recently performed at ISOLDE), lifetime measurements and laser spectroscopic studies to get a deeper knowledge of the shape-coexistence phenomenon.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Exotic decay of hot rotating nuclei near proton drip line

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Decay of hot and rotating medium-light and heavy compound nuclei (CN) , far from the stability or near the drip lines has become one of the main interesting topic. The standard statistical evaporation theory, which has been implemented in various statistical codes like HIVAP, PACE, CASCADE, GEMINI etc (based on various phenomenological models), can explain the trend of particle evaporation from excited compound nucleus for most of the nuclei in the vicinity of stability. However, far from the stability or near the drip lines, the nuclear properties along with the structure of the nucleus, undergo enormous change. So, decay properties of the nuclei near the drip lines are also expected to be different in comparison to the stable ones. In this respect, we have studied the decay of the compound nucleus ^{124}Ce (~40-60MeV), obtained from bombardment of ^{32}S beam of 120-150MeV energy on thin as well as thick ^{92}Mo target at IUAC, New Delhi. On evaporation of p, n, α etc sevaral exotic isotopes such as ^{121}La, ^{121,120}Ba, $^{117-120}$Xe, $^{118-121}$ Cs, ^{117} I, etc have been populated in excited states and the de exciting γ-rays from those isotopes have been detected by an array of 12 clover detectors (INGA). Experimentally obtained relative population of various isotopes have been compared with the relative population predicted by the PACE calculation. For most of the channels the experimental relative poulation are in agreement with the PACE calculation, except few interesting channels. Some of these interesting channels are multiple proton evaporation channels (2p, 3p, 4p). Figure.1 shows consistent enhancement of relative population of ^{120}Xe (4p) at various beam energy. Varying level density parameter, fission barrier etc. which are very important parameters in statistical model calculation near drip lines, the experimental huge enhancement of population of the isotopes could not be reproduced consistently altogether. In addition to the enhancement of mutiple proton channels, there are some enhanced evaporation channels which may be related to exotic clusters. It is interesting to note that normal alpha cluster evaporation channel in this exotic nuclei is in agreement with statistical model calculation. More detailed experimental data in comparison with statistical model calculation will be presented in this conference.

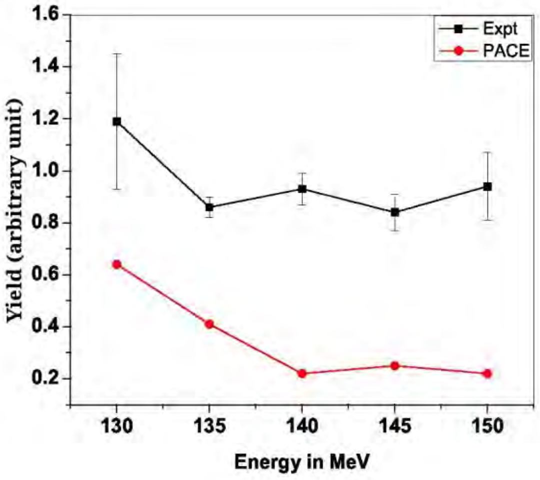

Figure 1*: Relative population of* ^{120}*Xe at different Energy*

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Single-Particle Strength in the Odd, Neutron-Rich Ni Isotopes

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Neutron-rich isotopes represent a steady source of new information on the behavior of the nucleus. Sometimes, unexpected phenomena occur such as halo-nuclei or the disappearance of the well-established magic numbers. Spin-isospin parts in the nucleon-nucleon interaction, e.g., the proton-neutron tensor force (in particular, the strongly attractive monopole parts) are expected to modify shell structure in exotic nuclei. These potential changes in the intrinsic shell structure are of fundamental interest.

Since the properties of ^{78}Ni are much debated, neutron-rich Ni, Co and Cu isotopes have been the object of much experimental effort. The study of the single-particle character of the first excited states of odd-A, n-rich Ni isotopes allows to document the effective single-particle energies (ESPE) of neutron orbitals around the Fermi surface, and represents a step forward in the understanding of the region and the nature of the NN interaction at large N/Z ratios. Detailed knowledge of neutron and proton ESPE in the vicinity of the ^{78}Ni doubly-magic shell closure will serve as a fundamental benchmark for the modelling of nuclear structure in regions with even larger N/Z ratios.

At the National Superconducting Cyclotron Laboratory we studied the distribution in single-particle strength in the neutron-rich ^{67,69,71}Ni isotopes via one-neutron knockout reactions, a well-established technique to address this specific issue. The secondary ^{68,70,72}Ni beams were produced by fragmentation reactions of a primary ^{82}Se beam impinging on a Be target, and further purification and separation of the beam was achieved with the A1900 fragment separator. The secondary beams were transported to the S800 large-acceptance spectrometer, tuned to accept the one-neutron knock-out fragments. The de-excitation γ rays were measured by means of the GRETINA tracking array.

The presentation will focus on the details of the study and present the measured spectroscopic factors giving detailed single-particle structure information.

This work was supported by the National Science Foundation under Grant No. PHY-0606007 and by the Department of Energy, Office of Nuclear Physics, under contract No. DE-AC02-06CH11357.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

The onset of triaxiality in neutron-rich rhenium isotopes

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Experiments that observe nuclear isomers provide insight into the composition of nuclei and enable tests of nuclear structure predictions. In general, isomers in heavy neutron-rich isotopes, at or beyond the line of stability, cannot be produced by conventional fusion-fission or fusion-evaporation reactions. Our approach has been to access these nuclei via multinucleon transfer or deep inelastic reactions. To maximise production cross-sections, neutron-rich targets and beams were chosen. Neutron-rich rhenium isotopes were populated using a pulsed or chopped ^{136}Xe beam produced by the ATLAS accelerator at Argonne National Laboratory, incident on gold-backed ^{187}Re and ^{192}Os targets. Gamma-ray emission from excited reaction products was measured using the Gammasphere detector array.

The region close to ^{190}W has been predicted to exhibit changes in nuclear deformation [1,2], transitioning from prolate, through triaxial, to oblate shapes as more neutrons are added. Recent experiments on heavy neutron-rich isotopes in the region (^{188,190}W and ^{191,193}Ir) [3,4] show signatures of a transition to triaxial shapes. Specifically, in ^{188}W and ^{190}W there is a decreasing trend of the reduced hindrances for the isomer decays in more neutron-rich nuclei. Whilst the significant signature splitting of the $h_{11/2}$ band in ^{191}Ir and ^{193}Ir points to these nuclei having non-prolate shapes, theoretical calculations predict significant changes in triaxiality for different 3-quasiparticle configurations [4]. Measurements of quasiparticle configurations in ^{189}Re and ^{191}Re will further the understanding of this transition into a triaxial regime in heavy neutron-rich nuclei.

The present focus is on the neutron-rich isotopes ^{187}Re, ^{189}Re and ^{191}Re. Previous experiments in this region identifed delayed γ-rays from isomeric states in ^{187}Re [5] and ^{191}Re [6], although a full level scheme is only known ^{187}Re. In addition to γ-ray spectroscopic studies, ^{187}Re,^{189}Re and ^{191}Re have also been the subject of particle transfer experiments (polarised t,α) on stable osmium targets, where low-spin excited states were examined [7]. In the current experiment, the $9/2^-[514]$ proton state and its associated rotational band were observed in the decay of 3-quasiparticle isomers in all three isotopes. The trends in the isomeric transition reduced hindrances and the aligned angular momenta of the $9/2^-[514]$ bands are related to shape changes across the isotopic chain, and can be used to test the inference of increasing triaxiality in the more neutron-rich isotopes.

This work is supported in part by the US Department of Energy, Office of Nuclear Physics, under contract No. AC02-06CH11357.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Beta decay to continuum states

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As one moves towards the driplines, an increasing fraction of beta decays will feed particle unbound states. An overview of the many physics consequences this has can be found in a recent review [1]. This contribution will focus on the mechanism behind beta-delayed particle emission, more specifically on whether decays proceed through resonances in a daughter nucleus or go directly into the continuum.

Halo nuclei, see [2] and references therein, constitute an extreme limit of nuclear structure and the two-neutron halo nuclei ^{6}He and ^{11}Li appear both to have beta-delayed deutron emission taking place directly into the continuum. For ^{11}Li this process is strong when measured in terms of beta-strength (the small energy window makes the branching ratio of order 10^{-4}), whereas cancellation effects reduces the strength for ^{6}He. The "two neutron to deuteron" overlap enters in the description of the process, and a much cleaner case would therefore be the beta-delayed proton decay of a single-neutron halo nucleus. Estimates of this process for ^{11}Be indicates that this will be a very rare process [3] due to the very low energy available; the maximum strength will only give a branching ratio of a few times 10^{-8}. Experiments at ISOLDE/CERN (the IS374 [3] and IS541 [4] collaborations) have looked for the ^{11}Be(βp)^{10}Be decay and results from them will be presented.

Two more general related subjects will be covered briefly as well. First, the standard definitions of beta strength in beta-delayed particle processes will be critically examined. There is currently an unfortunate dependency of the definition on the assumed reaction mechanism. I shall argue that a very simple experiment-based definition is conceptually superior to those employed e.g. in R-matrix analyses.

Finally, the decay mechanism question will be discussed in general with an emphasis on how resonant structures in the continuum may enter in the theoretical description.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Decay of the high-K isomer in the Z=104 nucleus ^{257}Rf

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Superheavy elements ($Z \geq 104$) owe their existence to nuclear shell effects, which prevent nuclei from spontaneous fission caused by the strong Coulomb repulsion between protons. The predictions for the location of the "island of stability", where relatively long-living nearly-spherical superheavy nuclei can be found, are sensitive to the gaps in the single-particle spectrum, and therefore the identification of the deformed single-particle states in somewhat lighter elements is needed. Of particular interest are the multi-quasiparticle high-K isomeric states in nuclei close to $Z = 100$ and $N = 152$ deformed shells. By identifying high-K isomeric states, and studying their decay to states with lower-K, we can learn about the shapes, single-particle structure, pairing correlations, and excitation modes of the heaviest nuclei.

The ^{257}Rf isotope was populated via the ^{208}Pb(^{50}Ti, n) fusion-evaporation reaction in an experiment using the Berkeley Gas-filled Separator (BGS) at the Lawrence Berkeley National Laboratory. Recent improvements in the beam intensity and the detector setup allowed detailed delayed γ-ray and electron decay spectroscopy of the decay of the known high-K isomeric state in ^{257}Rf. Thanks to higher statistics compared to earlier studies [1,2], the decay of this multi-quasiparticle isomeric state to a rotational band in ^{257}Rf could be confirmed and the underlying quasiparticle excitations identified. In addition, the results allowed re-interpretation of the isomeric states in ^{256}Rf [3]. These studies push the limit of a detailed superheavy-element spectroscopy further than ever before, for example, ^{257}Rf is the heaviest isotope for which a rotational band has been observed. In this contribution, the latest experimental results will be reported and their physics implications will be discussed.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Lifetime studies of ^{133}Cs

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Nuclei in the A~130 region have been shown to demonstrate a variety of nuclear shapes. Indeed, previous work carried out by Koike et al. [1] has shown that the underlying physics of odd-odd Cs isotopes and neighbouring nuclei can be understood through a triaxial structure. Garg et al. [2] demonstrated that the behaviour of odd mass Cs nuclei, such as ^{133}Cs, can be well described by a combination of both the particle-plus-rotor and particle-plus-vibrator models. This is because Cs (Z=55) nuclei form an important link in the study of the region of transition between primarily vibrational Sn (Z=50) nuclei, and highly deformed La and Ce (Z = 57, 58) nuclei.

In order to better understand the low-lying structures of ^{133}Cs, an experiment was conducted at IFIN-HH, Bucharest to measure lifetimes in the picosecond to nanosecond regime. A 31.5 MeV beam of ^{7}Li, provided by the TANDEM accelerator, impinged on a ^{130}Te target to exploit the fusion evaporation channel, ^{130}Te(^{7}Li, 4n)^{133}Cs. Gamma-rays were detected using an array of 8 high-purity germanium (HPGe) detectors and 11 lanthanum bromide ($LaBr_3$) detectors. The latter providing the capability to measure lifetimes down to ~50 ps.

The level scheme of ^{133}Cs observed in this experiment will be compared with previous studies [1,2,3]. Transition strengths, determined from the measured lifetimes will be used to probe the low-lying structure in these nuclei. This presentation will give preliminary results of the analysis.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Octupole correlations from a theoretical perspective

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Quadrupole deformation is a rather common characteristic of the ground state of atomic nuclei. It implies the breaking of rotational invariance and naturally yields to the useful concept of intrinsic states. The next relevant moment is the octupole one characterized by the breaking of reflection symmetry and pear-like shapes. Contrary to the quadrupole moment case, permanent octupole deformation in the ground state is rather scarce and it is only present in a few nuclei in the rare earth and the actinide regions. However, dynamical correlations around the reflection symmetric ground state are not negligible and therefore, octupole correlations are essential to describe the energy of low lying collective negative parity states and $E1$ and $E3$ transition strengths. They also have an impact on binding energies and derived quantities like nucleon separation energies. Among the theoretical models used to describe from different perspectives this phenomenon the mean field has proved to be a good candidate [1]. However, the dynamical character of octupole correlations in most of the nuclei imply the relevance of going beyond the mean field to improve the description. In our recent survey of octupole properties in even-even nuclei [2] the generator coordinate method (GCM) has been used to restore the broken reflection symmetry of octupole shapes and to take into account fluctuations on the octupole degree of freedom around reflection symmetric ground states. Realistic Energy Density Functionals (EDF) like various parametrizations of the Gogny EDF have been considered in the calculations (see also [3] for calculations with the recently proposed BCPM functional). The consistency among the results obtained with the different functionals give credit to the validity of our description and suggests that potential discrepancies with experiment have to be attributed to missing degrees of freedom.

In this talk, I will discuss the results obtained in [2,3] for excitation energies, transition strengths and ground state correlation energies of essentially all the relevant even-even nuclei. The comparison with available experimental data is quite reasonable all over the nuclear chart. However, systematic deviations are observed that point to missing degrees of freedom and deficiencies in the description. For instance, in Ref [4] the coupling between the quadrupole and octupole degree of freedom is considered in a few nuclei. The coupling seems to be small for the quadrupole deformed nuclei considered but a more systematic calculation covering spherical or near spherical nuclei is in order. The coupling to other degrees of freedom is being considered at present and preliminary results show the relevance of the coupling to pairing degrees of freedom.Systematic underestimation of the E3 strengths is also observed. We have focused on the validity of the rotational formula used to related intrinsic and laboratory frame quantities [5] and shown that the systematic underestimation can be traced back to the breaking of the rotational formula for near spherical systems. Systematic calculations considering angular momentum projection are very promising and substantially improve the comparison with experiment.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

The Nuclear Symmetry Energy: constraints from Giant Resonances and Parity Violating Electron Scattering

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The nuclear symmetry energy is a basic ingredient of the nuclear equation of state: it accounts for the energy cost per particle of producing a neutron to proton asymmetry in the nuclear medium. The accurate determination of this quantity impacts on the size of the neutron distribution in nuclei [1] as well as on isovector nuclear collective excitations [2,3]. The latter are characterized by an out of phase oscillation of neutrons against protons, being the restoring force proportional to the nuclear symmetry potential and, therefore, directly related to the symmetry energy. Parity violating electron scattering can provide a direct and model independent measure of the parity violating asymmetry. Similarly to clean parity conserving electron scattering experiments where the electromagnetic distribution in nuclei is determined, the parity violating asymmetry provide information on the weak charge distribution in nuclei, basically carried by neutrons [4].

Experimental and theoretical efforts are being devoted to the study of such complementary observables that can shed light on the properties of the nuclear symmetry energy. We will briefly discuss the theoretical study on the Isovector Giant Dipole Resonance [2] and present our new results for the Isovector Giant Quadrupole Resonance [3], which has been the object of, new exclusive, experimental investigation. Then, we also present our theoretical analysis of the parity violating asymmetry at the kinematics of the Lead (^{208}Pb) Radius Experiment (PREx) [4] and how it can be related with the properties of the symmetry energy. PREx completed an initial run in 2010 and additional beam time has been requested and recently approved. In addition, the measurement of the weak charge distribution in other nuclei such as ^{48}Ca is thought to provide complementary information to that of PREx. Fostered by this fact, a proposal for a new experiment on this nucleus (CREx) has been recently submitted to the Jefferson Laboratory. We will also discuss some theoretical results relevant for CREx.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Alpha Cluster Structure in ^{16}O

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The alpha cluster phenomenon in the light nuclei structure has been the subject of a longtime investigation since the proposal of the Ikeda diagrams [1], however the mechanism of the cluster formation is still not completely understood. In fact, if the clusters have a fairly rigid crystal-like or a gas-like structure remains an open question[2-3]. The interpretation of the Hoyle state as an α condensate brought a renewed interest to this subject, in particular to resonances analogous to the Hoyle state. In this context the study of the experimental evolution of the α-cluster phenomenon through (^{6}Li,d) transfer reactions has been performed in São Paulo [4]. Particularly important are the regions around the *n*α thresholds where the α-cluster structure states are predicted. The resonant states around the 4α threshold in the nucleus ^{16}O are the focus of the present contribution. The ^{12}C(^{6}Li,d)^{16}O reaction was measured at a bombarding energy of 25.5 MeV employing the São Paulo Pelletron-Enge-Spectrograph facility and the nuclear emulsion detection technique. Resonant states above the α threshold were measured and an energy resolution of 15-30 keV allows to define states previously unresolved. The angular distributions of the absolute cross sections were determined in a range of 4-40 degree in the center of mass system and up to 17 MeV excitation energy. The upper limit for the resonance widths in the crucial region of the 4α threshold was obtained. These values revealed to be at least a factor three smaller than the ones previously reported in the literature [5], indicating that the α cluster structure information on this region should be revised. Figure 1 shows an deuteron energy spectrum in order to illustrate the good resolution achieved and the narrow resonances observed in the present work.

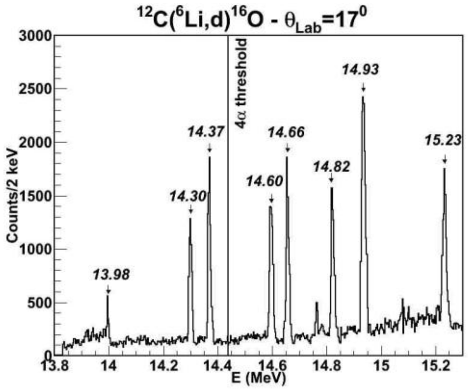

Figure 1: *Energy deuteron spectrum for θ_{lab} = 17° near the 4α threshold.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Extending the knowledge of neutron-rich nuclides by precision mass measurements with ISOLTRAP

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The mass is a unique property of an atomic nucleus reflecting its binding energy and thus the sum of all interactions. Precise measurements of nuclear masses of short-lived nuclides thus provide important insight into the structural evolution far from stability and serve for nuclear structure studies and nuclear astrophysics.

Such measurements are performed with the Penning-trap mass spectrometer ISOLTRAP at the on-line isotope separator ISOLDE/CERN. A mass uncertainty of routinely $\delta m/m = 10^{-8}$ can be achieved and the accessible half-life has been reduced to about $50\,\mathrm{ms}$. One challenge for these high-precision mass measurements is to produce a clean ion sample. The capability for isobar separation has been increased significantly by integration of a multi-reflection time-of-flight (MR-ToF) mass spectrometer. It provides enhanced purification of highly contaminated ion beams. The results of two successful measurement campaigns in the regions $Z = 30$ and $Z = 87, 88$ will be presented in this contribution:

(i) The mass of exotic ^{82}Zn has been determined for the first time. This nuclide has the most extreme neutron excess of the known $N = 52$ isotones and provides an important input with respect to the $N = 50$ shell gap, where mass models differ enormously in their predictions. Our data shows an enhancement of the neutron shell gap towards the doubly-magic ^{78}Ni. A special interest in this mass arises, since ^{82}Zn is also of relevance in nuclear astrophysics with respect to neutron-star crust compositions.

(ii) The masses of the isotopic chains $^{224-233}$Fr and ^{233,234}Ra have been determined, where many of them have been measured for the first time. Far beyond $N = 126$, this is one of the heaviest and most exotic ensembles accessible at ISOL facilities. In the case of ^{233}Fr, the new mass denotes its first precisely known observable. In this region, mass measurements elucidate collective effects such as the octupole deformation in the Ra isotopic chain. They are also of special interest because the predictions from mass models suffer from systematic deviations in this region and the number of known masses is still scarce. The impact of the data will be discussed along with technical developments at ISOLTRAP.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Low-lying dipole strength in exotic Ni isotopes

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The Pygmy Dipole Resonance (PDR) is a mode of nuclear excitation appearing at large neutron-to-proton imbalances in medium to heavy mass nuclei. Since the existence of this low-lying dipole mode is related to the neutron-proton asymmetry, the systematic investigation of the PDR can for instance contribute to the understanding of the symmetry energy in the equation-of-state of nuclear matter. This has an impact on the behavior of not only exotic nuclei, but also of objects of astrophysical interest, such as neutron stars.

Several experiments have been carried out in the past years using the R^{3}B-LAND setup at GSI in Darmstadt, in which the electric dipole strength of exotic nuclei has been studied. The experimental method was based on heavy-ion-induced electromagnetic excitation and the subsequent particle and photon decay. The measured E1 strength distribution of ^{68}Ni will be presented for the neutron-decay channels - with a special emphasis on the energy range in which the PDR is expected - and will be compared to other experimental data obtained by virtual photon scattering. The experimental dipole polarizability has also been extracted and is compared to recent theoretical calculations, allowing conclusions to be drawn on the neutron-skin thickness of ^{68}Ni and ^{208}Pb, and thus on the symmetry-energy parameters of the nuclear equation-of-state. Additional preliminary results on the E1 strength in other neutron-rich nickel isotopes will be also presented, revealing the presence of low-lying strength.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Microscopic description of ^{6}He

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Exotic nuclear structures can appear in the vicinity of the dripline. One particular example is the three-body structure and extended matter distribution of Borromean two-neutron halo systems. We want to address the underlying physics for these phenomena by performing microscopic structure calculations. To study three-body structures we have derived an explicit expression for the translational invariant overlap function for core+n+n in the framework of the ab-initio No-Core Shell Model, starting with a Slater determinant, harmonic oscillator basis. With these overlap functions we can now study two-particle halo structures of light nuclei. In particular, we have studied the halo structure of ^{6}He as a system consisting of ^{4}He and two neutrons.

A key result is visualized in Figure 1, which shows the overlap function of ^{6}He and ^{4}He plus two neutrons in the S=0, L=0 channel. These results are calculated with an SRG-evolved chiral NN interaction at N3LO [1] and what is noticeable is the correlation between the two neutrons, which is a characteristic of the halo structure.

By transforming our overlap functions to a hyperspherical harmonics basis it is possible to compare our microscopic calculations with earlier three-body calculations in a potential model [2]. We also performed studies of the "swelling" of the core. This effect is observed in our microscopic wave functions through an enlarged distance between the two protons in the ^{4}He-core.

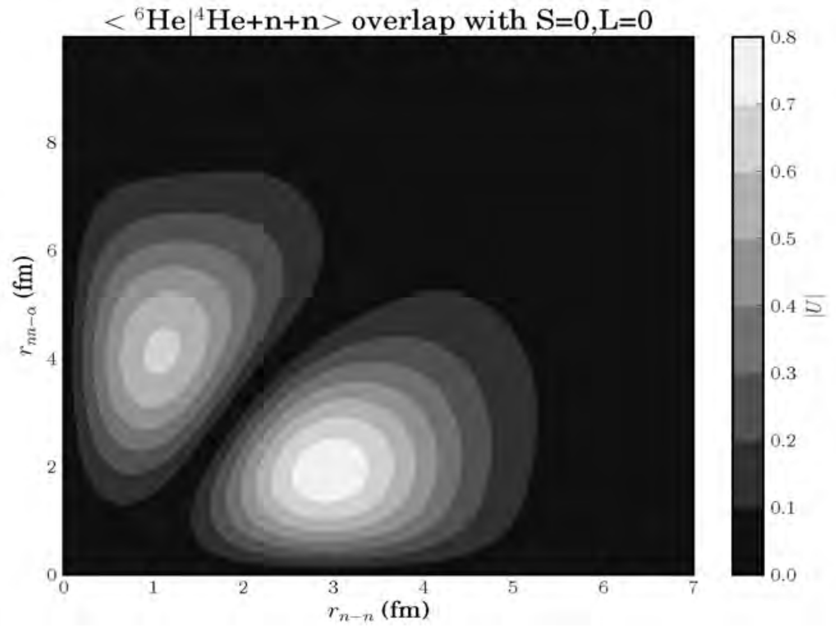

Figure 1: *Contour plot of the overlap function. Calculated with an SRG-evolved chiral N3LO interaction,* N_{max}*=14 and* $\hbar\omega$*=18.*

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Role of T=0 pairing in Gamow-Teller transitions and the ground states

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The strong attraction between nucleons is the basic ingredient for the pairing correlations. So far, the pairing interactions of like-nucleons with the isovector spin-singlet (T=1, S=0) channel has been mainly discussed. In fact, the attraction between protons and neutrons is even stronger in the isoscalar spin-triplet (T=0, S=1) channel which gives rise to the deuteron bound state. However the role of T=0 pairing is limited in nuclei because of large imbalance between neutron and proton numbers, and also the two-body spin-orbit interaction which breaks the S=1 pair more effectively than the S=0 pair. In this contribution, Gamow-Teller (GT) states in N=Z nuclei with the mass number A from 48 to 64 are studied by using Hartree-Fock-Bogoliubov + quasi-particle random phase approximation (HFB+QRPA) with Skyrme interactions [1]. The isoscalar spin-triplet (T=0,S=1) pairing interaction is taken into account in QRPA calculations. It is found in the context of SU(4) symmetry in the spin-isospin space that the GT strength of lower energy excitations is largely enhanced by the T=0 pairing interaction which works cooperatively with the T=1 pairing interaction in the ground state. A two-peaked structure observed recently in (p, n) reaction on ^{56}Ni [2] can be considered as a manifestation of the role of T=0 pairing in the GT collective states.

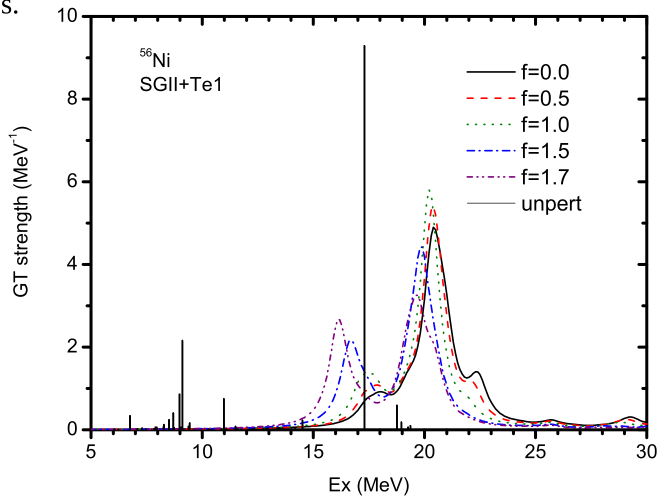

Figure 1: *Gamow-Teller strength in* ^{56}*Ni obtained by HFB+QRPA calculations with the Skyrme interaction SGII+Te1. The excitation energy is referred to the ground state of* ^{56}*Ni. The T=0 pairing interaction is included in QRPA changing the ratio factor* f *between T=0 and T=1 pairing interactions from* f*=0.0, 0.5, 1.0, 1.5 and 1.7. The solid lines show the unperturbed strength without RPA correlations. The QRPA strength is smoothed out by a Lorentzian function with a width* $\Gamma = 1$ *MeV.*

We further discuss the role of T=0 pairing in the ground states of N=Z nuclei in pf shell region [3]. It is pointed out the strong spin-orbit coupling give a large quenching of T=0 pairing correlations, while the strength of T=1 pairing remains the same under the strong spin-orbit coupling.

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The evolution of the Z=28 shell gap towards ^{78}Ni: Neutron-rich Cu isotopes

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Two different measurements in order to study shell-structure of neutron-rich Cu nuclei in the region of ^{78}Ni (Z=28,N=50) have been carried out at LNL (Laboratori Nazionali di Legnaro, Italy) and RIKEN Nishina Center (Japan), respectively. In the first work, neutron-rich ^{69}Cu and ^{71}Cu isotopes, have been populated via a multi-nucleon transfer reaction of a ^{76}Ge beam onto a thin ^{238}U target at LNL in June 2010. Data have been taken using the AGATA Demonstrator array coupled to the PRISMA magnetic spectrometer. Lifetimes of the excited states in Cu nuclei have been measured by the Cologne Differantial Plunger dedicated to the usage of the AGATA Demonstrator with the PRISMA spectrometer at LNL. The knowledge of the electromagnetic transition matrix elements deexciting the states of interest in Cu nuclei, obtained through lifetime measurements, will provide determination of the collective or single-particle character of these states, therefore the essential information on the shell gap size and evolution of the Z=28 shell gap around ^{78}Ni. The results and their comparison with the large-scale shell model predictions will be discussed in the firs part of the contribution. In the second work, excited states of neutron-rich ^{75}Cu and ^{77}Cu isotopes have been accessed through the beta decay of ^{75}Ni and ^{77}Ni at RIKEN in November 2012. Neutron-rich reaction fragments, after fissioning of ^{238}U at an energy of 345 MeV/nucleon on a thick ^{9}Be target, have been selected and identified by the BigRIPS fragment separator. For the implantation of the ions as well as detection of the emmitted beta particles, a stack of DSSSDs (Double-Sided Silicon Strip Detectors) has been used as active stopper. EURICA (EUroball RIken Cluster Array) has been located at the end of the BigRIPS fragment separator and the ZeroDegree spectrometer at the RIBF in order to collect gamma rays emmitted from the reaction products. After correlation between implantation and electron decay events in the silicon stack, the gamma-ray energy spectra have been obtained for the ^{75}Cu and ^{77}Cu isotopes. Identification of the location of low-lying excitations in these nuclei has been studied as test of the microscopic interaction in the fpg shell. Excited states of such exotic nuclei will allow us to trace the evolution of the proton single-particle states in the vicinity of ^{78}Ni. Detailed information will be discussed in the contribution.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Superdeformed band and 2α-cluster structure of ^{47}V

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Much attention has been devoted to understanding superdeformed (SD) rotational bands in ^{36}Ar--^{48}Cr nuclei. The collective aspects of these SD bands are particularly interesting subjects for nuclear structure studies. We have performed $2\alpha+^{40}$Ca cluster model calculations for ^{48}Cr and have shown that the observed energy spectra and E2 transitions probabilities are reproduced with good coincidence [1]. The nucleus ^{47}V provides the first link in the chain of 2α–cluster or 8p-nh states in A=44-48 nuclei. It is also very interesting to know if 2α–cluster structure is extended successfully to odd-A nuclei in which the symmetry breaking due to spin-orbit force would be stronger. Figure 1 shows the experimental positive-parity SD band of ^{47}V [2], which are expected to be largely of $2\alpha+^{39}$K nature.

We want to investigate the ^{47}V nucleus using a $2\alpha+^{39}$K orthogonality condition model (OCM). The model space is described by a set of wave functions $\Phi_J = \{4!4!39!/47!\}^{1/2} \mathcal{A}\{\phi(\alpha)\phi(\alpha) [[U_{N_2l_2}(\boldsymbol{R}),U_{N_1l_1}(\boldsymbol{r})]_{L_{12}}, \phi_I(^{39}\mathrm{K})]_J\}$, where ϕ's are the antisymmetrized internal wave functions and $U_{N_2l_2}(\boldsymbol{R})$ and $U_{N_1l_1}(\boldsymbol{r})$ are oscillator functions for the relative motions. The core state $\phi_I(^{39}\mathrm{K})$ is assumed to be $(sd)^{-1}(0,2)$ configuration. Therefore, the model wave function is generated as a direct product of $\phi_I(^{39}\mathrm{K})$ and the relative wave functions:$(N_2,0)\mathrm{x}(N_1,0)\mathrm{x}(0,2)$. Table 1 shows the SU(3) classification of the Pauli-allowed states in the positive-parity. The lowest total quanta $N=N_2+N_1=24$ states are the important core excited states such as the 8p-1h (16,6) state. The calculation of the OCM equation is in progress.

Figure 1: *The experimental positive-parity SD band of* ^{47}*V.*

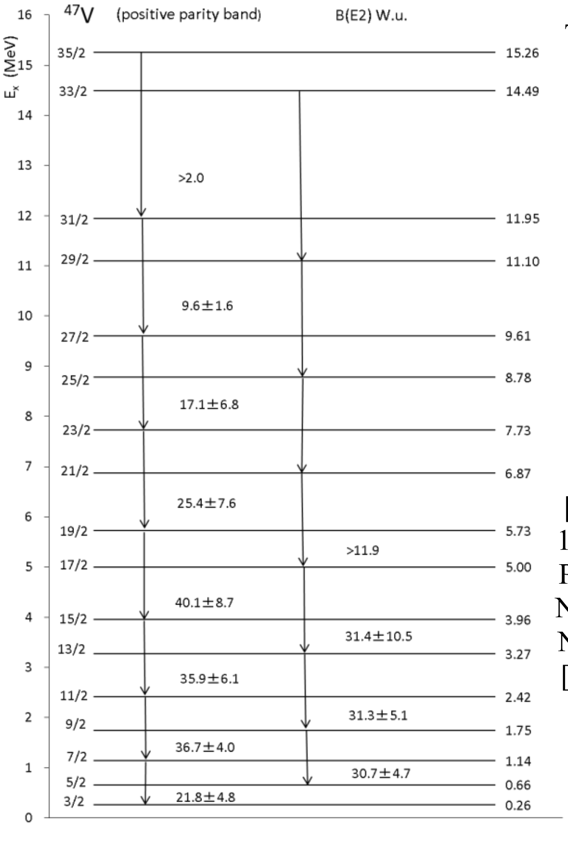

Table I. The Pauli-allowed states of ^{39}K+α+α system.

N	$(\lambda, \mu)^n$
24	$(18,2)^2(16,3)^2(14,4)^3(12,5)^2(10,6)^3(8,7)^2(6,8)^3(4,9)^2(2,10)^2$ $(17,4)(15,5)(13,6)(11,7)(9,8)(7,9)(5,10)(3,11)(1,12)$ $(16,6)(12,8)(8,10)(4,12)(0,14)$
N	$(N-2,0)(N-4,1)(N-6,2)...(2,N/2-2)(0,N/2-1)$ $(N-1,1)(N-3,2)(N-5,3)...(3,N/2-1)(1,N/2)$ $(N,2)(N-2,3)(N-4,4)...(2,N/2+1)(0,N/2+2)$

[1]T. Sakuda and S. Ohkubo, Phys. Rev. C49, 149(1994); C51, 586(1995); C57, 1184(1998); Prog.Theor. Phys. Suppl. No.132, 103(1998); Phys. At. Nucl. 65, 703(2002); Nucl. Phys. A712, 59(2002); Nucl. Phys. A744, 77(2004).

[2] F. Brandolini et al., Nucl. Phys. A693, 517(2001).

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Nuclear shape evolution through lifetime measurement in neutron rich nuclei

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A new interest for very exotic nuclei further away from the valley of stability arises due to the possibility to use refined experimental methods. In particular, the neutron rich side of the valley of stability still offers a lot of interesting features to be discovered e.g. the evolution of nuclear shapes. Our recent experiment on nuclei around A = 100 (Z~40, N~60) aims at discovering part of these features trough lifetime measurements and will help understanding nuclear shape evolution in neutron rich unstable nuclei. In this mass region, shapes are changing rapidly, which is reflected in the theoretical calculations by the prediction of occurrence of prolate, oblate, or triaxial shapes. These predictions vary as a function of the theoretical model used, thus experimental measurements will have important implications.

The neutron-rich isotopes were produced trough a fusion-fission reaction induced by a ^{238}U beam in inverse kinematics and performed at GANIL. The aim of this experiment was to extend information on the evolution of the collectivity in this mass region by measuring the lifetimes of excited states in more neutron-rich nuclei and up to higher spins. A and Z identification of the fission fragments was performed with the VAMOS spectrometer, while the EXOGAM spectrometer was used for the γ-ray detection. The RDDS (Recoil Distance Doppler Shift) method has been applied to extract the lifetime of excited states. To our knowledge this is the first experimental attempt to perform a RDDS experiment on fission fragments, which are identified in A and Z on an event-by-event basis. Results on the analysis performed to achieve the identification of the fission fragments up to Z=54 and A=150 and on the new lifetime values will be presented.

Description of pairing in finite systems of like fermions with quartets

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We propose a description of the ground state correlations induced by a general pairing Hamiltonian in a finite system of like fermions in terms of four-body correlated structures (quartets). These are real superpositions of products of two pairs of particles in time-reversed states. The ground state of a system with an even number of particles is represented as a product of quartets all different from one another and, depending on this number, an extra collective pair.

We show that this formalism provides an exact representation of the ground state of a constant pairing Hamiltonian and we provide the (semi)analytical form of the quartets. In a general case, we determine the quartets variationally through an iterative sequence of diagonalizations of the Hamiltonian in restricted model spaces. The extra pair (if any) is also determined variationally. In case of pairing in a spherically symmetric mean field, both the quartets and the extra pair are characterized by a total angular momentum $J = 0$.

We provide realistic applications of the quartet formalism for the Sn isotopes with valence neutrons in the 50-82 neutron shell. Exact ground state correlation energies, occupation numbers and pair transfer matrix elements are reproduced to a very high degree of precision. Comparisons with a traditional approach to pairing like the particle-number projected-BCS approach, in which the ground state is described as a condensate of identical $J = 0$ pairs, or with a more sophisticated approximation based on a product of distinct $J = 0$ pairs [1], evidence a much higher quality of the approximation based on quartets.

We apply the quartet formalism to the excited states as well and show that it allows an accurate description of the lowest seniority 0 and 2 eigenstates of the pairing Hamiltonian.

A simplified representation of the ground state as a condensate of quartets is eventually discussed and found to improve considerably upon its direct pair analogue, i.e. the particle-number projected-BCS approach.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Study of 13Be through isobaric analog resonances in the Maya active target

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The Spectroscopy Group in Leuven has intensively studied halo nuclei and other related drip line systems. Recently, the ground state of the unbound nucleus ^{13}Be has been investigated.

The determination of the sequence of its low-lying states can shed light on the evolution of the N = 8 shell closure towards the dripline. While a resonance in ^{13}Be at about 2 MeV above the neutron emission threshold is confirmed and identified as a $d_{5/2}$ state, the situation regarding other lower-lying states is more controversial and there are indications of a disappearance of the N=8 shell closure.

^{13}Be also provides important information for the modeling of the two-neutron halo nucleus ^{14}Be. According to theoretical works [1], the $d_{5/2}$ resonance would have to be lower than the observed 2 MeV in order to reproduce the two-neutron separation energy in ^{14}Be. The discrepancy can be solved by an inversion of the $2s_{1/2}$ and $1p_{1/2}$ orbitals or including excitations or deformations of the ^{12}Be core in the models.

To study the ground state of ^{13}Be, we populate its isobaric analog resonance in ^{13}B through the resonant scattering of ^{12}Be nuclei on protons. Once the IAS is populated, isospin conservation allows decay (to the entrance channel) via emission of a proton that will be detected in our setup.

The ^{12}Be beam (post-accelerated for the first time in REX-ISOLDE) was sent into Maya, an active target, in which the detection gas isobutane contained the protons that were the target of the reaction. Maya is a gaseous detector [2], providing three-dimensional reconstruction of the tracks of the charged particles traversing the gas volume. Identification of the particles is achieved via the specific energy loss, the total energy deposited and the length of the paths. An array of Si and CsI detectors covers the wall opposite to the beam entrance, to detect forward-emitted light ions which are not stopped in the gas volume. The detector has been successfully used in a number of reaction experiments [3-6].

The particular timing characteristics of REX beam, combined with those of the gas detector, made the experiment particularly challenging.

Preliminary results will be presented during the oral presentation.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Proton-neutron pairing and alpha-type condensation in nuclei

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The common understanding of proton-neutron pairing correlations, whose fingerprints are currently investigated in $N \approx Z$ nuclei, relies on Cooper pair mechanism and BCS-type models.
An alternative approach, based on four-body alpha-like structures and which conserves exactly the particle number and isospin symmetry, has been recently proposed in Refs [1,2]. In this approach the ground state of N=Z nuclei is described as a condensate of alpha-like quartets built by proton-neutron, neutron-neutron and proton-proton collective pairs. The comparison with exact shell model calculations indicates that the quartet condensation model gives a very accurate description of pairing correlations in N=Z nuclei, much better than the BCS-type models [3,4]. It is also shown that proton-neutron pairing and alpha-type condensation are important not only for N=Z nuclei but also for nuclei with excess neutrons. In the latter case the condensate of alpha-like quartets coexist with the condensate of the neutron pairs in excess relative to the N=Z isotope. Using the framework of the model mentioned above, we shall discuss the role of proton-neutron pairing and alpha-like quarteting in the symmetry and Wigner energy and the competition between isovector/isoscalar pairing and nuclear deformation. The discussion will be focused on nuclei with neutrons and protons above the closed cores ^{16}O, ^{40}Ca and ^{100}Sn.

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Evolution of Collectivity in the Vicinity of ^{208}Pb

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A systematic experimental programme has been started to derive the evolution of quadrupole collectivity near the heaviest stable doubly-magic nucleus ^{208}Pb. Here, $B(E2; 0^+ \rightarrow 2^+)$-values are being measured via relativistic Coulomb excitation. Despite the fact that the energy, $E(2^+)$, and strengths, $B(E2; 0^+ \rightarrow 2^+)$, of the first $I^\pi = 2^+$ state in even-even nuclei is one of the key quantities in nuclear structure physics, surprisingly little is known about the latter in the direct neighbourhood of the heaviest stable doubly-magic nucleus ^{208}Pb.

In October 2012 an experiment was conducted within the PRESPEC-AGATA campaign [1] at the UNILAC-SIS accelerator complex at the GSI Helmholtzcentre for Heavy-Ion Research in Darmstadt, Germany. Following the fragmentation of a 1 AGeV ^{208}Pb primary beam, heavy Pb, Hg, and Pt secondary beams were prepared by the GSI Fragment Separator [2] and focused onto a gold target foil. Gamma-rays were measured by AGATA [3] and HECTOR [4], and the outgoing ions were discriminated by the LYCCA detector system [5].

Results from the ongoing data analysis will be presented and compared to contemporary nuclear structure model calculations.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Mean-field calculation including proton-neutron mixing

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We have developed a new code for mean-field calculation based on the nuclear density functional theory (DFT) including an arbitrary mixing between protons and neutrons. This is a first step towards the density functional calculation including proton-neutron (p-n) pairing. The p-n pairing is a long-standing open problem in nuclear physics, and its possible relations to various phenomena in nuclei have been repeatedly discussed. However, in spite of recent impressive experimental progress and theoretical studies over the years, the understanding of the p-n pairing is still unsatisfactory. We address this problem taking the DFT approach. To treat the p-n pairing within the DFT framework, one needs to generalize the quasiparticle states as mixtures of protons and neutrons. Isospin, then, is not a good quantum number for quasiparticles. In connection with this extension of quasiparticles, one also needs to extend energy density functionals to those with mixing between protons and neutrons. The density functionals are extended in such a way that they become invariant under rotation in isospin space [1].

As a first step towards DFT calculation including the p-n pairing, we here consider Hartree-Fock (HF) calculation without pairing correlation including the above-mentioned p-n mixing. We have developed a code for this p-n mixing calculation by extending a code "HFODD" [2], which is a solver of nuclear HF or Hartree-Fock-Bogolyubov (HFB) problem with the Skyrme density functionals. In the p-n mixing calculation, we control isospin of the system by adding the so-called isocranking term $-\vec{\lambda}\cdot\hat{\vec{T}}$ to the Hamiltonian ($\hat{\vec{T}}$ is the total isospin operator). This is an analogy with the cranking calculation for high-spin states. So far, we have performed test calculations for $A = 14$ and $A = 48$ isobars. For $A = 14$ isobars, we have calculated the energies of the isobaric analogue states with $T = 1$, and found that the IAS with $T_z = 0$ (the excited 0^+ state of ^{14}N) is reproduced well as a state consisting of single-particle states with the p-n mixing. We have also performed isocranking calculation for ^{48}Cr. We have seen that we can obtain higher-isospin states with different values of $\langle\hat{T}^2\rangle$ and $\langle\hat{T}_z\rangle$ by isocranking the ground state of ^{48}Cr with $T \simeq 0$. The isocranking calculation is a simple linear constraint method. We have also implemented in our code an improved method for constraining known as "the augmented Lagrange method" [3]. This can be utilized, e.g., for the calculation of the excitation energies for high-isospin states in a single nucleus, from which we can evaluate the nuclear symmetry energy.

In this presentation, we show some results of the HF calculations with p-n mixing, and we also briefly touch on our future perspectives: e.g., application of the DFT including p-n pairing to charge-exchange reactions in r-process nucleosynthesis.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Experimental results on the Pygmy Dipole Resonance

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The so-called Pygmy Dipole Resonance (PDR) has been established as an additional structure of low-lying electric dipole (E1) strength in atomic nuclei [1]. The presence of the PDR in many medium-heavy to heavy nuclei and the smooth variation of its properties lead to the assumption that the PDR is a newly discovered collective mode. However, the detailed structure and the degree of collectivity of the PDR are a matter of ongoing discussions.

We have investigated the PDR experimentally using the methods of real-photon scattering as well as $(\alpha, \alpha'\gamma)$ coincidence experiments at E=136 MeV. While the photon scattering experiments provide information on the systematics of the PDR as well as its fine structure and the fragmentation of the E1 strength [2], the alpha scattering experiments allow the investigation of the structure of the individual excited states [3,4]. The comparison of the two methods have revealed a surprising structural splitting of the E1 strength into two energetically separated parts. Together with the investigation of the isoscalar and isovector E1 strength in QPM and RQTBA calculations these experimental observations allow for an identification and interpretation of the underlying structures of the low-lying E1 strength in atomic nuclei [4]. An overview on results in the N=82 and Z=50 mass region will be presented.

* supported by the Helmholtz Alliance EMMI (HA216/EMMI), the DFG (ZI 510/4-2 and SFB 634) and the EU (EURONS Contract No. RII3-CT-2004-506065).

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

RMF+BCS Description of Some Traditional Neutron Magic Isotones

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The relativistic mean-field (RMF) approach has been extensively applied for the description of the ground state properties of nuclei located in various regions of the nuclear chart with remarkable success [1-5]. The main advantage of the RMF approach over other non- relativistic theories is that it provides the spin-orbit interaction in the entire mass region in a natural way which is very crucial to study the unstable nuclei near the drip-line. In this communication we present a brief description of the part of the results obtained in extensive study of the nuclei constituting the isotonic chains for the traditional neutron magic numbers N = 8, 20, 28, 50, 82 and 126, as well as 40. These studies have been carried out within the framework of relativistic mean field plus state dependent BCS approach [6,7] including the deformation degree of freedom [8](throughout referred to as deformed RMF+BCS).

Similar to the situation met in the case of isotopes of proton magic nuclei [6], it is found that the wave function of single particle proton resonant states lying in the continuum close to the proton Fermi level in the proton rich isotones near the proton drip-line with neutron number N = 28, 50, 82 and 126 as well as 40, have characteristics similar to the wave function of bound proton single particle states. Due to this the pairing interaction can connect the resonant states with the bound ones resulting in the increase of total pairing energy. This phenomenon plays an important role in accommodating a few extra particles in the resonant states resulting in an extended proton drip-line . However, contrary to the large extension of the neutron drip-line in the case of proton magic nuclei due to the ability of accommodating many neutrons by the low lying high angular momentum single particle neutron resonant states, here in the case of magic isotones the addition of more protons for a fixed neutron number is strongly restricted by the disruptive effect of the Coulomb force amongst protons. Besides this restriction, it may be emphasized that the similarity of wave functions does make the overlap of the bound and continuum resonant states appreciably large and resulting large pairing gap energy of the proton single particle states for the nuclei near the proton drip-line of the isotonic chains with neutron number N = 40, 50, 82 and 126. These proton rich nuclei, respectively, ${}^{46}_{26}\mathrm{Fe}_{20}$, ${}^{96}_{46}\mathrm{Pd}_{50}$, ${}^{154}_{72}\mathrm{Hf}_{82}$ and ${}^{220}_{94}\mathrm{Pu}_{126}$ are the representative examples of the proton rich nuclei in the N = 20, 50, 82 and 126 neutron magic isotonic chains and describe their features in detail obtained within the RMF+BCS approach. This aims to elucidate the typical features of the calculated potential, single particle wave function and the pairing gap energy etc.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Binding Energy Curve of $N = Z$ Atomic Nuclei

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The saw-tooth phenomenon on the binding energy curve of $N = Z$ nuclei is due to the low binding energy between the α particles. It was suspected by Gamow to be of van der Waals type, found here to be deuteron bonds. The binding energy per nucleon, in absolute value, of an α particle is larger than any other combination of 4 nucleons. Therefore, the binding energy per nucleon is low for odd-odd $N = Z$ nuclei and maximum for even-even $N = Z$ nuclei. The assumption of $N = Z$ nuclei to be an assembly of α particles and deuteron bonds predicts the binding energy of the 64 first $N = Z$ nuclei with a rms deviation of $0.25\ MeV$.

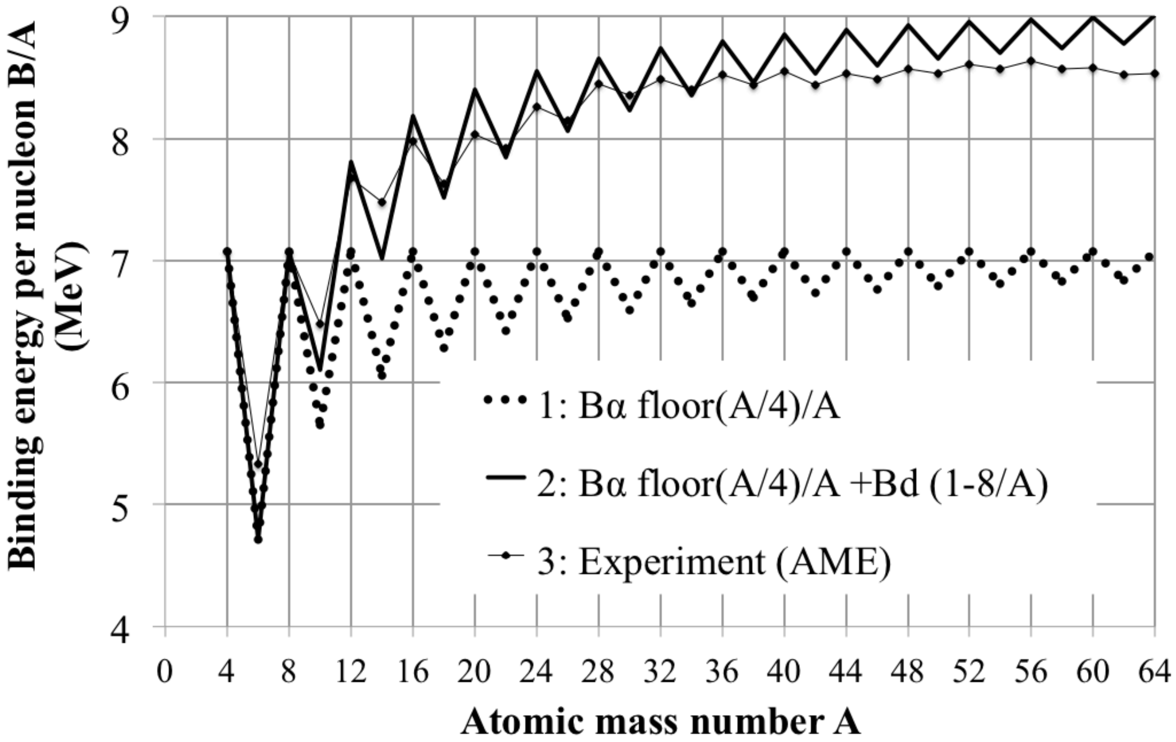

Figure 1: *Saw-tooth, even-odd, zig-zag, four-shells or pairing effect of the binding energy (absolute value) of $N = Z$ nuclei. – Curve 3 shows the experimental data. It "suggests an α model for light nuclei "[1]. An odd $N = Z$ nucleus has almost the same* ***total*** *binding energy as its neighbors for unbound α particles with and without excess nucleons (curve 1). Adding the binding energy of the $\alpha - \alpha$ bonds (B_α) as deuteron bonds (B_d) explains the mean increasing binding energy* ***per nucleon*** *with increasing A (curve 2). The rms deviation between the calculated curve 2 and the experimental curve 3 from AME [2] is $0.25\ MeV$.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Nuclear structure and reaction studies with exotic nuclei at FRS-ESR

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Nuclear physics with exotic nuclei in storage rings was pioneered at the SIS-ESR facility in combination with the fragment separator FRS. Already the first experiments in the early 90'ies gave access to ground-state properties like masses and half-lives and indicated the reserach potential of this novel approach. Many new data have been obtained and interesting phenomena have been explored, e.g. the mass surface was mapped over large areas of the chart of nuclei, isomer studies of long-lived states (with half-lives of the order minutes) became possible, the modification of decay properties for highly-charged high-Z exotic nuclei was observed, and new decay modes, like the beta-decay to bound final states, were studied for the first time. A few years ago, direct reaction experiments on internal targets using inverse kinematics have started : transfer (p,d) and pickup (p,gamma) reactions of astrophysical interest have been performed with stable isotopes at energies approaching the Gamow-window, while elastic (p,p) and inelastic (p,p') scattering experiments have been performed with secondary beams of the unstable double magic isotope 56Ni quite recently (see contribution by M. von Schmid to this conference). In this talk, achievements will be reviewed, recent results will be presented, and future perspectives will be addressed.

Dipole strength on the tail of the giant dipole resonance

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Dipole strength distributions in Z=42, in N=50 and in N near 82 nuclides were studied in photon-scattering experiments at the electron accelerator ELBE of HZDR and at the HIγS facility of TUNL, Durham. On the basis of simulations of γ-ray cascades, intensities of inelastic transitions were estimated and subtracted from the experimental intensity distributions that include the resolved peaks as well as a quasicontinuum formed by unresolved transitions. Further, the intensities of ground-state transitions to the ground state were corrected for their branching ratios. The photoabsorption cross sections obtained in this way are combined with (γ,n) and (γ,p) data and give information about the dipole strength distributions in the energy range from about 4 MeV up to the giant dipole resonance (GDR). Enhanced dipole strength compared to Lorentz-like approximations of the tail of the GDR is found in the energy range from about 5 MeV up to the particle thresholds. The experimental results are compared with predictions of various theoretical approaches, such as QRPA, QPM, RQTBA and shell model. To investigate possible consequences of the enhanced dipole strength for reaction rates of photo-nuclear and radiative-capture reactions, calculations of cross sections using the statistical code TALYS were carried out, in which the experimental dipole strength distributions were used as an input. The results are compared with those obtained by using standard approximations for the input strength functions.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Beta-delayed neutron spectroscopy using trapped ions

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Many basic nuclear-structure properties (β-strength functions, branching ratios, decay widths, etc.) of neutron-rich nuclei can be determined from delayed-neutron measurements and are needed to improve nuclear-structure models and empirical predictions used to determine the properties of the many isotopes that remain unmeasured. Delayed-neutron branching ratios are also crucial for determining how the neutron-rich isotopes synthesized in r-process environments decay back to stability to form the isotopic abundances observed today. In addition, precise β-delayed neutron spectroscopy of neutron-rich nuclei yield valuable information for nuclear energy, stockpile stewardship, and homeland security applications. However, the fundamental nuclear data available today for individual nuclei is limited.

For the first time, β-delayed neutron spectroscopy has been performed by identifying neutron emission from the momentum imparted to the nucleus. When radioactive ions are confined in a radiofrequency-quadrupole ion trap, the recoiling daughter nucleus and emitted radiation emerge from the ~1-mm^3 trap volume and propagate through vacuum with negligible scattering. Measurements of both the neutron branching ratio and energy spectrum can be performed with good energy resolution, high efficiency, and minimal backgrounds by inferring the neutron momentum from the detection of recoil ions in coincidence with the β particles [1]. Therefore, the problems associated with direct neutron detection can be circumvented using trapped radioactive ion samples.

This novel approach to study β-delayed neutron emission was successfully demonstrated by delivering fission products from a ~1-mCi ^{252}Cf spontaneous-fission source to the Beta-decay Paul Trap [2] instrumented with plastic scintillator ΔE-E telescopes for β detection, position-sensitive MCP detectors to determine the recoil-ion momentum, and HPGe detectors for γ-ray detection. Results from a recent measurement of the β-delayed neutron standards ^{137,138}I as well as other neutron-rich isotopes will be presented.

This work was supported by U.S. DOE under Contracts DE-AC52-07NA27344 (LLNL), DE-AC02-06CH11357 (ANL), DE-FG02-98ER41086 (Northwestern U.), NSERC, Canada, under Application No. 216974 and the Department of Homeland Security.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Study of the level structure of ^{108}Ag

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The transitional nuclei, as the name suggests, have a character which is between spherical and axially symmetric deformed nuclei. These nuclei violate the axial symmetry and can be described using the triaxial deformed mean field. The transitional nuclei may have valence particles and holes in the high *j*-orbitals. The three mutually perpendicular angular momenta vectors corresponding to the particle angular momentum, the hole angular momentum and the core angular momentum can form a right handed or a left handed system giving rise to a chiral geometry. In mass A$\sim$ 110 transitional region, some of the odd-odd isotopes of Rh, Ag and In have been predicted to have multiple chiral bands owing to their triaxial shapes, using the RMF calculations [1]. The ^{106}Rh nucleus is known to have a pair of chiral bands[2]. In this present work, we have investigated the high spin structure of ^{108}Ag nucleus and a pair of degenerate dipole bands have been observed.

The nucleus ^{108}Ag was populated using the reaction ^{11}B + ^{100}Mo at 39 MeV beam energy. The experiment was performed using the Indian National Gamma-detector Array (INGA) with 18 Compton Suppressed HPGe clover detectors [3]. From the E_γ-E_γ and E_γ-E_γ-E_γ coincidence analysis, the level structure of ^{108}Ag was build. A pair of negative parity degenerate dipole bands have been observed in this nucleus. The spin and parity of the levels have been assigned using angular correlations and polarization measurements. The microscopic Triaxial Projected Shell Model (TPSM) approach has been used to qualitatively understand the nature of observed dipole bands [4]. The observed level energies and the ratios of the electromagnetic transition probabilities of the degenerate bands are very well reproduced by the present model.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

High Resolution ^{148}Nd(^{3}He,nγ) Two Proton Stripping Reaction and the structure of the 0_2^+ State in ^{150}Sm

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The challenge of achieving high resolution in binary reactions involving an outgoing high energy neutron is solved by detecting the γ-ray decay of populated excited states in an array of escape suppressed HPGe detectors in coincidence with fast neutrons detected in a wall of scintillator detectors 2m down beam of the target. The selectivity of the arrangement is of the order of 1 in 1000. The time-of-flight difference is sufficient to separate fast neutrons from direct reactions from a large background of statistical neutrons from fusion-evaporation reactions. We have used the AFRODITE spectrometer at iThemba LABS to select γ-rays from the ^{148}Nd(^{3}He,nγ)^{150}Sm reaction, at a beam energy of 25 MeV, to pick out states populated in ***L=0*** two proton transfer. Our interest is in the wavefunction of the 0_2^+ state at 740 keV in the N=88 nucleus ^{150}Sm which is one of only two excited states observed [1] in 2β2ν double β-decay. The importance of understanding the microscopic configurations of these 0_2^+ states, and the ground 0_1^+ states of the parent and daughter nuclei, has been stressed in a recent review article [2]. The better the transition matrix elements can be calculated, the more accurately an effective neutrino mass can be extracted. There is also the ambition of using the double γ-ray decay from the 0_2^+ states to give a four-fold coincidence with the two electrons to improve the sensitivity of experiments so that the level of $\approx 10^{24}$ y partial half-life can be achieved. This is the estimated sensitivity required to detect 2β0ν neutrinoless double decay to determine the Majorana/Dirac nature of neutrinos. The N=88 nuclei have remarkable features; they are at a peak in the $|M(E3)|^2$ strength of $0_1^+ \rightarrow 3_1^-$ transitions for even-even nuclei as a function of neutron number; they also have very strong E0 transitions from the band built on the 0_2^+ states to the ground state bands. It has been established [3,4] that the 0_2^+ states in N=88 and 90 nuclei are not β-vibrations but 2p-2h states lowered into the pairing gap by configuration dependent pairing. They are classic examples of 'pairing isomers' forming a 'second vacuum' [3] on which a complete set of excited deformed states are built that are congruent to those built on the 0_1^+ ground state. We have made extensive spectroscopic measurements in the nucleus ^{150}Sm reporting here on the first observation of consistent E1 transitions in deformed nuclei from the levels in the first excited 0_2^+ band to the lowest negative parity bands. The data will be discussed in terms of possible permanent octupole deformations [5].

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Charge Radii of Extremely Light and Heavy Rubidium Isotopes

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In this contribution we report on changes in mean square charge radii of the very light and very heavy Rb isotopes obtained from collinear laser spectroscopy experiments carried out at TRIUMF. Nuclear spins, moments and changes in mean square charge radii obtained from optical hyperfine structure and isotope shift measurements have contributed a wealth of information on nuclear structure [1]. When measured over long isotopic chains, these data provide a systematic layout of the development of exotic nuclear shapes. One of the first elements studied systematically over a wide range of isotopes is Rb [2]. Changes of nuclear charge radii with respect to the closed shell isotope ^{87}Rb (N=50) are shown in Figure 1. Included in the Figure are also the droplet model isodeformation curves, where a deformation of $\beta=0$ was assumed for the closed shell isotope ^{87}Rb. As can be seen from this Figure, the Rb isotopes develop a strongly deformed shape when going away from the shell closure to both the neutron rich and neutron deficient side. However whereas this strong deformation is reached by a sudden jump around N=60 for the neutron rich isotopes, it is reached by a more gradual increase for the neutron deficient side. Naively it is expected that the deformation culminates at mid-shell around N=39 between the major shell closures at N=28 and N=50, and that the influence of the closed shell at N=28 will stabilize the shape back to spherical. This is assuming that N=28 is also a shell closure for those highly proton rich isotopes and that subshell closures do not influence the charge radii drastically. The mean square charge radii of the newly measured ^{74,75}Rb [3] will help address these questions. On the neutron rich side the recently measured ^{98m,99}Rb mean square charge radii will allow to investigate the extent to which the sharp change in shape also seen in the Sr isotopes between N=58 and N=60 carries through into the adjacent Rb isotopes. The data for those isotopes are currently being analyzed. Previously measuresd changes in mean square charge radii for ^{76,98}Rb [2] have been confirmed and improved.

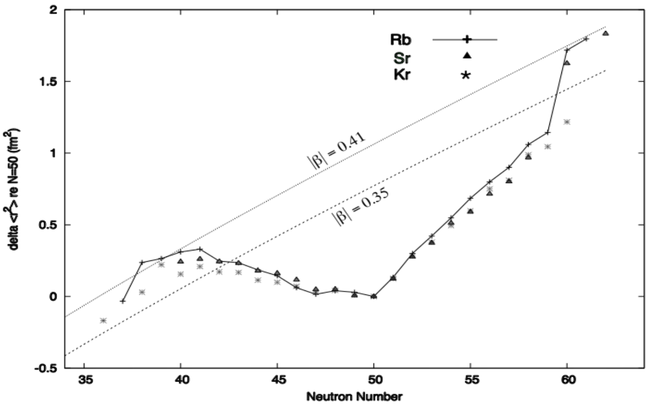

Figure 1: Changes of mean square charge radii of Rb (+), Sr (⑩) and Kr (*) isotopes [2,3,4,5]

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Ab initio Bogoliubov coupled cluster theory

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Standard coupled cluster (CC) theory is an ab initio method that has been applied for accurate calculations of nuclei, including medium-mass nuclei, starting from microscopic two- and three-body forces. While CC calculations have been extended beyond doubly magic nuclei, the method is based on an exponential ansatz for the wavefunction that builds excitations on top of a single Slater determinant. For truly open-shell nuclei which exhibit superfluid properties, a single Slater determinant cannot approximate their behavior. An extension of CC theory which utilizes a symmetry-breaking reference state, the Bogoliubov vacuum, captures the superfluid properties of open-shell nuclei without compromising much on computation.

The formalism of Bogoliubov coupled cluster theory, built upon a reference state determined by the solution of the Hartree-Fock-Bogoliubov equations, will be presented along with typical truncation schemes necessary for computational purposes. The current status of results for realistic nuclei with Bogoliubov coupled cluster theory in m-scheme formalism will also be discussed.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Signature Splitting in $7/2[633]_\nu$ band of ^{175}Hf

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It is substantially understood that the moment of inertia and its dependence on angular momentum is slightly different in case of odd-A nuclides as compared to the neighboring even-even nuclides. This affirmative difference in the moment of inertia and its dependency on angular momentum originate due to larger deformation and weaker pairing correlations observed in case of odd-A nuclides [1]. In the present paper, we performed the Particle Rotor Model (PRM) calculations which emphasizes on the role of angular momentum dependence of rotational parameter (B) and Rotational Correction Term (RCT) in explaining the notable signature splitting in one-quasineutron ($7/2[633]_\nu$) band observed in ^{175}Hf [2]. In Fig 1(a-c), we present precise PRM calculations which incorporate higher order Coriolis mixing along with following possibilities of free parameters: (i) angular momentum dependence of rotational parameter; (ii) rotational correction term which originates from recoil term of the total Hamiltonian (iii) both (i) & (ii) above collectively. In Fig 1(a-c), we present the comparison of PRM calculations [3] with the experimental data. From Fig 1(d), it is well apparent that the low spin region of this band ($7/2 \le I \le 19/2$), shows a negligible signature splitting but at higher spin values the band exhibits the pronounced staggering behavior. For minute inspection of this band, we consider the low spin region ($7/2 \le I \le 19/2$) (Fig. 1(a)), higher spin region ($19/2 \le I \le 33/2$) (Fig. 1(b)) and complete spin range of this band (Fig 1(c)) individually. From Fig 1(a), it is clear that only the angular momentum dependence of rotational parameter plays an important role in explaining the low spin region of this band which exhibits almost negligible signature splitting. But at higher spin values, it is only the rotational correction term which reproduces the magnitude as well as phase of staggering successfully as shown in Fig. 1(b). The calculations for other similar one-quasiparticle rotational bands in various nuclides will elaborate; how angular momentum dependence of rotational parameter and rotational correction term affect existing nuclear structure information pertaining to observed signature effects in one-quasiparticle bands. The Financial support from Department of Science & Technology, Govt. of India is gratefully acknowledged.

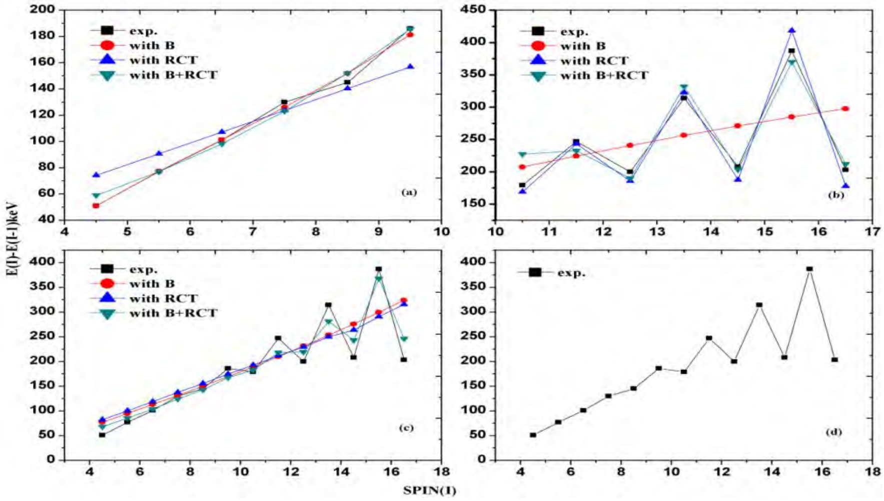

Figure 1: *The Coriolis mixing calculations with different possibilities of free parameters*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Investigating the strength of the $N = 34$ subshell closure in ^{54}Ca

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Over the past few decades nuclear structure studies have focused intensively on the evolution of the traditional magic numbers away from the valley of β stability. In the neutron-rich fp shell, for example, the discovery of a new subshell closure at $N = 32$ became evident from experimental measurements of $E(2_1^+)$ and $B(E2)$ reduced transition probabilities along the Ca [1], Ti [2, 3] and Cr [4, 5] isotopic chains, a characteristic that is reproduced rather well by the spherical shell model with effective interactions such as GXPF1 [6] and KB3G [7]. Another important manifestation of the GXPF1 interaction is the prediction of a significant subshell closure at $N = 34$ in Ca and Ti isotopes, however, this was found to be in contrast with experimental results for ^{56}Ti [3, 8], leading to the development of the modified interaction GXPF1A [9] and the most recent version, GXPF1B. Importantly, the predicted strength of the $N = 34$ subshell closure in ^{54}Ca remains relatively large in the GXPF1-based interactions, while some other models indicate a much weaker shell closure. Clearly, experimental input on the matter is essential to help resolve the situation.

In order to address this issue, the structures of ^{53}Ca and ^{54}Ca were investigated using in-beam γ-ray spectroscopy at the Radioactive Isotope Beam Factory, operated by RIKEN Nishina Center and Center for Nuclear Study, University of Tokyo. A radioactive beam containing ^{55}Sc and ^{56}Ti was employed to populate excited states in neutron-rich Ca isotopes via nucleon knockout reactions, and the structures of the reaction products were deduced by measuring $\gamma\gamma$ coincidences. Several new γ-ray lines have been assigned, including a strong candidate for the $2_1^+ \rightarrow 0_1^+$ transition in ^{54}Ca. The results will be discussed in terms of the energy systematics along the Ca isotopic chain, and modifications to shell-model effective interactions based on the new findings will be presented.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

The Continuum time-dependent Hartree-Fock method for giant resonances

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Time-dependent approaches are useful in tackling dynamic processes in nuclei, such as collective motion of a single nucleus, and collisions between nuclei. The basic mean-field approach is the *time-dependent Hartree-Fock* (TDHF) method. It has been widely applied to giant resonances, fusion, deep-inelastic collisions and transfer reactions [1].

In all or most applications of nuclear TDHF, the processes occur above particle emission threshold. With wave functions represented on a spatial grid, the bounday conditions at the edge of the calculation region become a significant issue as particles are emitted.

The simple conditions of periodic or reflecting boundaries can cause unphysical artefacts in observables. Methods to mitigate unphysical behaviour include the use of extended regions of complex absorbing potentials or masking functions [2]. These methods can be made to work, with some computational cost, by judicious tuining of parameters, but are never exact for arbitrary outgoing flux.

We present an exect method for implementing outgoing wave boundary conditions, based on a Green's function approach. We apply it to the case of giant monopole resonances in light doubly-magic nuclei, showing that the results agree exactly with computationally-punitive calculations performed in extremely large boxes. An example, in the case of an isovector giant monopole resonance in ^{40}Ca, is shown in Figure 1.

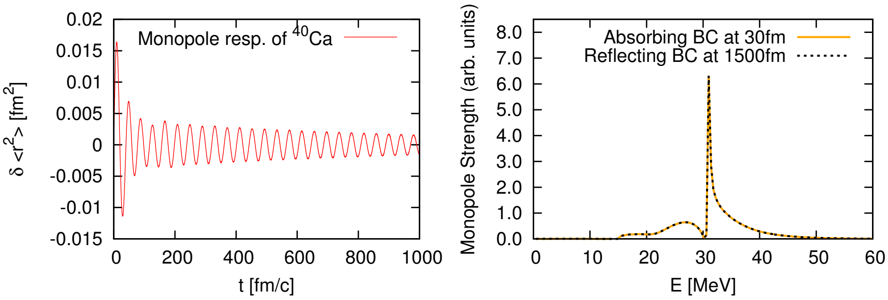

Figure 1: *Time-dependent monopole response of ^{40}Ca (left) and the associated strength function (right), adapted from [3].*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Investigation of high K states in ^{252}No and the new focal plane detector for S^3.

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In the last decades exhaustive investigations have been performed on the decay of deformed nuclei in the transfermium region around N=152 and Z=102, where enhanced stability is observed. Nuclei in this region are produced with cross sections ranging from nb to μb, high enough for detailed decay studies. Moreover, this region is characterized by the presence of K isomerism which may enhance the stability of such nuclei against α-decay and spontaneous fission (e.g. ^{270}Ds [1]). This phenomenon is explained by the presence of a high single-particle level density with high angular momentum just below and above the deformed shell gaps predicted at Z=102 and N= 152.

The investigation of the Nobelium region (Z=102), thus, delivers data in a region close to the domain of superheavy nuclei, where our knowledge of single-particle spectra and of pairing correlations is particularly limited. This will provide information relevant for the next shell closure which is expected to be at Z=114, 120, or 126 and N=184 for spherical superheavy elements ([2] and reference therein).

In this contribution I will first report on the successful discovery of an isomeric state in ^{252}No [3] and the recent results of the investigation of the rotational band built upon this isomeric state [4] performed at the Accelerator Laboratory of the University of Jyväkylä using the RITU gas-filled spectrometer and the JUROGAM array spectrometer. The last experiment helped assigning the structure of the isomer on the basis of purely experimental data and disentangle between different theoretical interpretations. New triaxial self-consistent Hartree-Fock-Bogoliubov calculations using the D1S force and breaking time-reversal as well as z-signature symmetries have been performed showing a good agreement with present measurements. I will then give an overview of K isomeric states found in N=150 and N=152 isotones nuclei; this comparison will provide important information and feeds self-consistent theories.

Finally, I will briefly describe the new focal plane detection set-up SIRIUS that will be built in the framework of Spiral 2 coupled with the high-intensity stable beams of the superconducting linear accelerator of GANIL and combined with the new Super Separator Spectrometer S^3. The Sirius spectrometer, which has been designed for identification of fusion evaporation residue through decay tagging, will provide important information on nuclear deformation, single particle properties, and resistance against fission under rotation. Such studies will univocally provide information concerning the location of deformed proton and neutron shell gaps, along with the ordering of single-particle levels. The ordering of the single-particle orbitals will provide a possibility to test the shell model for extreme nuclear deformations and will help us better understand the structure of the SHE close to the island of stability.

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Nuclear collective excitations in a Fermi liquid model

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The nuclear collective excitations are studied in a Fermi liquid model using the nucleon-nucleon interaction of the linear sigma-omega model as an input[1]. the nuclear collective excitation energies of different values of l are obtained, which are fitted with the centroid energies of the giant resonances of spherical nuclei, respectively. In addition, it is pointed out that the iso-vector giant resonances except $l = 1$ correspond to the modes that protons are in the creation state and neutrons are in the annihilation state, and vice versa. Some mixtures of the nuclear collective excitation states with different values of l are predicted.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Interpreting spectra determined using a multi-channel theory of coupled nuclear clusters

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A multi-channel algebraic scattering (MCAS) method [1] has been used to obtain spectra of a number of light-mass nuclei, which are treated as a two-cluster system, in these cases a nucleon plus nucleus. The MCAS method gives both sub-threshold and resonance states of the nuclei in question. To date, collective models have been used to specify the interactions between the nucleon and low-lying states of the nucleus that form the compound. For the case of the carbon isotopes, these studies have been complemented by sufficiently complex and complete shell-model calculations. Comparisons with the shell model results provide new insights into the validity of those from MCAS.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Search for a halo nucleus in Mg isotope through the measurements of reaction cross sections towards the vicinity of neutron-drip line

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During the past several tens of years, our knowledges about the features of exotic nuclei have been much enhanced. In 1980s, neutron halo structure of neutron drip-line nucleus, which is one of the most notable abnormal features of exotic nuclei, have been found [1]. Since 1990s, the vanishing of the N = 20 magic number for neutrons have been extensively studied and discussed in so-called island of inversion region, which includes neutron-rich Ne, Na, and Mg isotopes. In those studies, the inversion of amplitudes between sd-normal and pf-intruder shells has been considered along with nuclear deformation.

In this presentation, precise reaction cross section data for Mg isotopes, which have been recently measured at RIKEN, RI-beam Factory to probe nuclear sizes of Mg isotope will be reported. Using secondary beams from intense ^{48}Ca beam (345 MeV/u) and BigRIPS fragments separator, reaction cross sections for ^{24} ^{38}Mg have been obtained, and especially large cross section of ^{37}Mg has been observed for the first time. The deformation features of Mg isotope and the possible halo structure originated from pf-intruder shell in ^{37}Mg will be discussed from the present data. The results of the analysis with the microscopic double-folding model (DFM) and anti-symmetrized molecular dynamics (AMD) calculation [2, 3] will be also introduced.

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Neutron Skin Thickness of ^{208}Pb and Constraints on Symmetry Energy

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The symmetry energy term of the nuclear equation of state (EOS) is relevant to the size, structure and dynamic properties of neutron stars and various astrophysical simulations, *e.g.* neutron star cooling, X-ray burst, supernova, and nucleosynthesis. Even at and below the saturation density the symmetry energy parameter is poorly known. The first order density dependence of the symmetry energy, called *slope parameter*, is of particular interest since it is directly related to the baryonic pressure in a neutron rich matter [1].

The nuclear EOS can be studied by precisely measuring the proton and neutron density distributions or the difference between the proton and neutron radii in neutron rich nuclei, *e.g.* $^{208}\mathrm{Pb}$. The proton density distribution of $^{208}\mathrm{Pb}$ was well determined by electron scattering experiments. The neutron radius has been studied by proton elastic scattering [2], anti-protonic atom X-ray [3], and parity-violating asymmetry in electron scattering [4]. The experimental data have, however, large uncertainty due to model-dependence of the strong interaction (the former two), and statistical uncertainty (the last).

As an alternative method, we have precisely determined the electric dipole ($E1$) response of $^{208}\mathrm{Pb}$ by using electromagnetic excitation via proton inelastic scattering at very forward angles. The experiment has been carried out at the Research Center for Nuclear Physics, Osaka University employing a 295 MeV polarized proton beam, accelerated by cascade cyclotrons, and high-resolution spectrometer *Grand Raiden*. The details can be found in publications [5]. The nuclear dipole polarizability of $^{208}\mathrm{Pb}$ has been determined as α_D=20.1(6) fm$^3/e^2$ by inversely-energy weighted sum-rule of the measured $E1$ reduced transition probability combining with existing data. The dipole polarizability is closely correlated with the neutron skin thickness: difference between the proton and neutron radii [6]. With help of mean-field calculations, the neutron skin thickness of $^{208}\mathrm{Pb}$ has been determined as 0.168(22) fm including the model-uncertainty [7]. This result constrains the slope parameter as $L = 46 \pm 15$ MeV. The allowed region of L is small. Reasonably consistent values are reported from other experimental methods [1], theoretical predictions [8], and astrophysical observation [9].

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Evolution of octupole collectivity in ^{221}Th

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The Ra-Th region around $A\approx220$ offers some of the best examples of reflection-asymmetric, octupole shapes in nuclei. In odd-A nuclei, this phenomenon is manifested in terms of so-called parity-doublet structures. While several even-even nuclei are well studied, there is not much data on odd-A, proton-rich isotopes. These nuclei are of particular interest due to the coexistence and competition between quadrupole and octupole collectivity. The role of nucleon alignments in influencing shape changes can be studied, in a regime where octupole correlations are substantial. Further, the appearance of novel excitation mechanisms like rotation-induced condensation of octupole phonons [1] can be explored.

Excited states in ^{221}Th were populated through the ^{208}Pb(^{16}O,3n) reaction, at a beam energy of 86 MeV. The Indian National Gamma Array (INGA), consisting of 19 Compton-suppressed clover Ge detectors, was used to record γ rays emitted by the reaction products. The previously reported decay scheme for ^{221}Th [2] has been substantially modified and extended up to spin (39/2) $\hbar$ in the yrast sequence. In addition, a new non-yrast structure, with interleaved positive and negative parity sequences has been identified, with transitions up to spin (25/2) $\hbar$. A number of transitions linking the non-yrast and yrast structures have also been observed. Near-degenerate parity doublet structures similar to those observed in the heavier odd-A Th isotopes ^{223,225}Th are not evident in ^{221}Th (Fig. 1). Several arguments support a $7/2^+$ assignment for the ground state in ^{221}Th, with a dominant contribution from a K=1/2 configuration, leading to the absence of parity doublets. The moment of inertia of the positive parity states shows a pronounced increase at higher spins (Fig. 1), while the intensity in the negative parity sequence decreases rapidly, features which can be interpreted as an increase in quadrupole as compared to octupole collectivity. Cranking calculations have been performed, using the universal parameterization of the Woods-Saxon potential, including deformations (β_λ) up to λ=4, which indicate nucleon alignments beyond 0.20 MeV. The intrinsic electric dipole moments (D_0) deduced for the yrast structure (Fig. 1), along with the moments of inertia, suggest a dynamic variation of both quadrupole and octupole collectivity with spin.

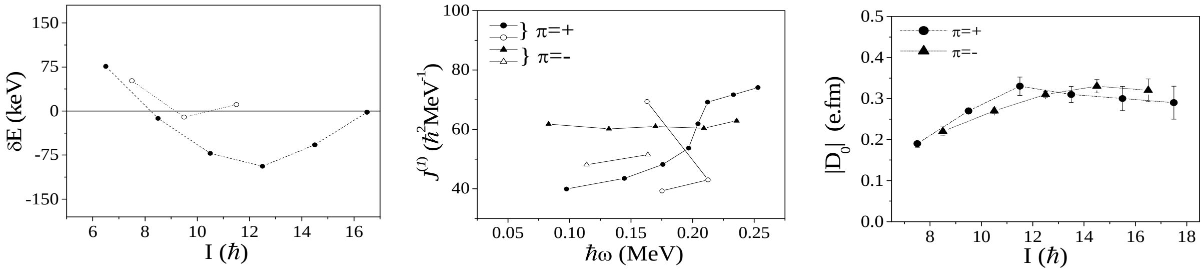

Figure 1: *Energy splitting between positive and negative parity states, kinematic moments of inertia, and intrinsic electric dipole moments (from left to right), deduced from the observed structure of ^{221}Th. The closed and open symbols in the first two panels represent yrast and non-yrast states, respectively.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

^{16}O-^{16}O clustering in superdeformed states of neutron-rich Sulfur isotopes

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Structures in excited states of neutron-rich sulfur isotopes are discussed focusing on clustering in superdeformed states.

Cluster structures develop in light nuclei. Typical examples are beryllium isotopes. Beryllium isotopes have developed 2α cluster structures, and valence neutrons are distributed around the 2α clusters. Sulfur isotopes are analogous isotopes of beryllium isotopes. It is because α and ^{16}O have double-closed shell structures and systems that have two ^{16}O clusters and valence neutrons form sulfur isotopes. In fact, existence of superdeformed states that contain two ^{16}O structure components is predicted in ^{32}S [1,2].

In this talk, studies of excited states in sulfur isotopes by using the antisymmetrized molecular dynamics and the generator coordinate method (GCM) are discussed. The GCM basis are obtained by energy variation with quadrupole deformation parameter β constraint. By the GCM calculation after parity and angular momentum projection, wave functions of ground and excited states are obtained.

In ^{35}S, superdeformed states are obtained. Dominant components of them have neck structures, and proton density distribution of them are similar to that of superdeformed states in ^{32}S, which are predicted to contain two ^{16}O cluster structure components. It suggests superdeformed states contains two ^{16}O cluster structure components in ^{35}S.

Both of clustering and deformation are important for understanding structures in sd-shell region as well as p-shell region.

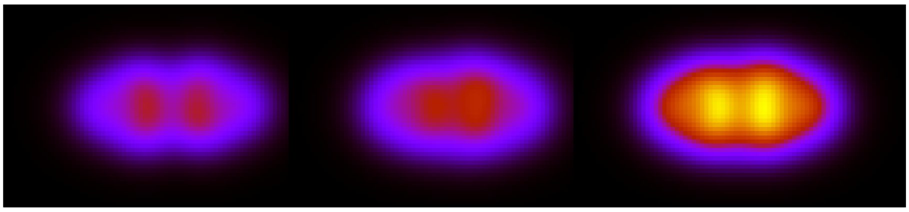

Figure 1: *The proton (left), neutron (center) and total (right) density distributions of a dominant component of superdeformed states in* ^{35}*S.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Cluster correlations and various deformed states in ^{42}Ca

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Structures in deformed states in mass number $A \sim 40$ region have been investigated by using the deformed-basis antisymmetrized molecular dynamics (AMD) and the generator coordinate method (GCM) focusing on coexistence of various rotational bands and cluster structures. In this talk, structures in low-lying states in ^{42}Ca and other topics are reported.

Drastic structural changes by low-excitation energy are significant characteristics of nuclear system, and coexistence and mixing of deformed structures and cluster structures are typical phenomena. In $A \sim 40$ region, low-lying largely deformed bands have been confirmed experimentally in ^{36,38,40}Ar, ^{40,42}Ca, and ^{44}Ti. Coupling of cluster correlations in deformed states has been also discussed in this mass region such as α-cluster structure in the normal-deformed band in ^{40}Ca and the ground-state band in ^{44}Ti.

In ^{42}Ca, deformed states and clustering behaviors have been observed experimentally. A rotational band built on the $J^\pi = 0^+_2$ (1.84 MeV) state ($K^\pi = 0^+_2$ band) has been observed by γ-spectroscopy experiments[1,2]. α transfer reactions to ^{38}Ar populate the $J^\pi = 0^+_1$ and 0^+_3 (3.30 MeV) states strongly[3], which suggests these states contains much α–^{38}Ar cluster structure components. In order to understand structures in ^{42}Ca, both of deformations and clustering should be take into account.

In this study, various deformations and α–^{38}Ar clustering are taken into account by the deformed-basis AMD and the GCM. By the calculations, the $K^\pi = 0^+_2$ band is reproduced, and coexistence of two more $K^\pi = 0^+$ rotational bands with $4p2h$ and $8p6h$ configurations are predicted. The band head of the $4p2h$ band corresponds to the experimental $J^\pi = 0^+_3$ state. $B(E2)$ values of in-band transitions of the $K^\pi = 0^+_2$ band are consistent with experimental data. The members of the ground-state and $4p2h$ bands contain α–^{38}Ar cluster structure components, which is consistent with results in which the $J^\pi = 0^+_1$ and 0^+_3 states are strongly populated by ^{38}Ar(^{6}Li, d) reactions. It is necessary to consider clustering and various deformations for understanding low-lying states in $A \sim 40$ region.

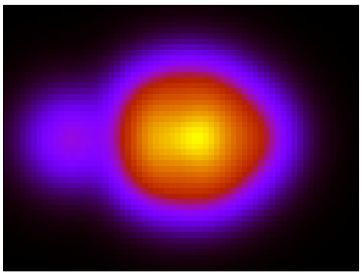

Figure 1: *The density distribution of an α-^{38}Ar cluster structure contained in the $4p2h$ band.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Polarization corrections to single-particle energies

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A straightforward definition of polarization corrections to single-particle energies is based on using the odd-even mass energy differences [1]. Within the energy-density-functional (EDF) methods, one can independently calculate the ground-state energies of even and odd systems. The latter ones are obtained by blocking specific orbitals in odd systems, whereby for a spherical state with total angular momentum j one obtains $(2j+1)/2$ twice-degenerate energies of deformed states, see Fig. 1.

In this work we analyze the relationship between the EDF methods and the polarization corrections obtained within the Quasiarticle Random Phase Approximation (QRPA) (for a recent representation of the model, see Ref. [2]). We compare results obtained within the full particle-vibration coupling (PVC) model with those obtained within the restricted polarization model and equivalent to the EDF results.

The QRPA equations are solved within a fully self-consistent approach and by keeping the complete interaction in the PVC vertices [3]. We show that the PVC method includes polarization diagrams that make it sensitive to ultraviolet divergences of the Skyrme EDFs. It is important to stress that in the case of density-dependent interactions, a comprehensive comparison between the EDF and QRPA approaches is meaningful only after the removal of self-interaction (SI) corrections in the PVC method [4]. These terms are important when one refers to the EDF odd-even mass differences computed as the ground state energies. Moreover, they are about of the same magnitude as the PVC corrections, and have opposite signs.

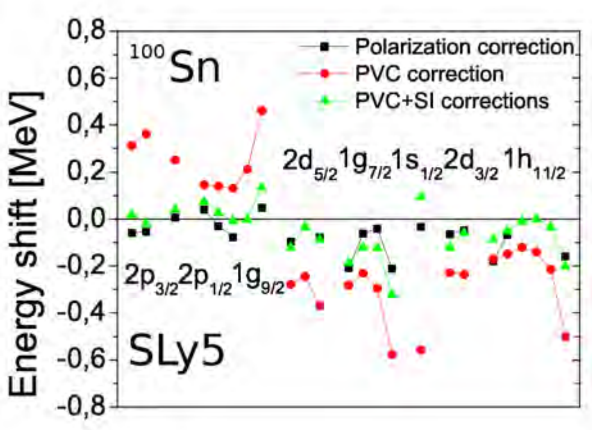

Figure 1: The PVC corrections to single-particle energies obtained within the restricted polarization model (circles), compared with those obtained by removing the SI terms (triangles), and by using the blocked EDF method (squares). The results for nine neutron orbitals around the Fermi surface in ^{100}Sn are presented. Each deformed suborbital is twice degenerate.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Nuclear Structure Experiments Beyond the Neutron Dripline

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In order to measure properties of nuclei with the most extreme neutron to proton ratios, it is necessary to develop techniques to study nuclei beyond the driplines. For the neutron dripline these nuclei are currently accessible up to fluorine. Several laboratories around the world have the capability to produces nuclei beyond the dripline and measure their decay. This typically involves the reconstruction of the invariant mass spectrum which requires coincidence measurement of the neutrons around zero degrees with the charged fragments (deflected away from zero degrees with a bending magnet).

Recent results of single neutron emitters include ^{12}Li, ^{15}Be, ^{21}C, ^{25}O, and ^{28}F. In addition, interesting results have also been achieved for the two-neutron emitters ^{10}He, ^{13}Li, ^{16}Be, and ^{26}O. In ^{16}Be the decay of a “di-neutron” like configuration was proposed and in ^{26}O first indications for two-neutron radioactivity were observed.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Hindered Proton collectivity in ^{28}S: Possible Magicity at $Z = 16$

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The reduced transition probability $B(E2; 0^+_{gs} \to 2^+_1)$ for the proton-rich nucleus ^{28}S was obtained experimentally using Coulomb excitation at 53 MeV/nucleon [1]. The experiment was performed using the RI Beam Factory accelerator complex at RIKEN Nishina Center. The resultant $B(E2)$ value 181(31) e^{2}fm^4 is smaller than the those of neighboring $N = 12$ isotones and $Z = 16$ isotopes. The proton and neutron transition matrix elements, M_p and M_n, for the $0^+_{gs} \to 2^+_1$ transition were evaluated from the present result and the $B(E2)$ value of the mirror transition in ^{28}Mg [2]. The double ratio $|M_n/M_p|$ of the $0^+_{gs} \to 2^+_1$ transition in ^{28}S was obtained to be $(1.9 \quad 0.2)N/Z$, demonstrating the hindrance of proton collectivity relative to that of neutrons. $|M_n/M_p|$ of neighboring $N = 12$ isotones and $Z = 16$ isotopes are close to N/Z, showing that the hinderance does not appear in these nuclei. These results indicate the emergence of the magic number $Z = 16$ in the $|T_z| = 2$ nucleus ^{28}S.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Chiral symmetry in nuclei

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Chirality is a novel feature of rotating nuclei. Because the chiral symmetry is dichotomic, its spontaneous breaking by the axial angular momentum vector leads to doublets of closely lying rotational bands of the same parity. Pairs of bands possibly due to the breaking of the chiral symmetry will be presented for the nuclei of ^{102}Rh and ^{134}Pr. The results for ^{102}Rh will be presented for the first time.

Reduced transition probabilities in ^{134}Pr are compared to the predictions of the two quasiparticle plus triaxial rotor and interacting boson fermion-fermion models. The experimental results do not support the presence of static chirality in ^{134}Pr underlying the importance of shape fluctuations. Only within a dynamical context the presence of intrinsic chirality in ^{134}Pr can be supported [1-3].

Excited states in ^{102}Rh, populated in the fusion-evaporation reaction ^{94}Zr(^{11}B, 3n)^{102}Rh at a beam energy of 36 MeV, were studied using the INGA spectrometer at IUAC, New Delhi. The angular correlations and the electromagnetic character of the gamma-ray transitions observed were investigated in details. A new chiral candidate sister band was found in the level-scheme of ^{102}Rh. Lifetimes of exited states in ^{102}Rh were measured by means of the Doppler-shift attenuation technique. Reduced transition probabilities in ^{102}Rh are compared to the predictions of the two quasiparticle plus triaxial rotor and interacting boson fermion-fermion models. The experimental results do not support the presence of static chirality in ^{102}Rh. Behavior of the transition probabilities in ^{102}Rh shows similarities with transition probabilities in the case of ^{134}Pr.

The analysis of the wave functions of chiral candidates bands in odd-odd nuclei, in the framework of the interacting boson fermion-fermion model, shows that nuclei where both the level energies and the electromagnetic decay properties display the chiral pattern, as well as those where a pair of twin bands is only close in excitation energy, do not sizably differ in geometry. In both of them the possibility for angular momenta of the valence proton, neutron and core to find themselves in the favorable, almost orthogonal geometry is present, but not dominant. The difference in the structure of the two types of chiral candidates nuclei can be attributed to different β and γ fluctuations, induced by the exchange boson fermion interaction of the interacting boson fermion-fermion model. In both cases the coupling of the proton and neutron quasi-particles to the shape degrees of freedom is the dominant mechanism, leading to a weak chirality of dynamical origin [3].

Our investigations show that the nuclei of ^{102}Rh and ^{134}Pr present properties typical for dynamic chirality.

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First 5/2$^+$ state of ^{23}O

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The first unbound excited state of ^{23}O has been measured via one-neutron knockout reaction from the ^{24}O beam with the proton target in inverse kinematics at the beam energy of 62 MeV/nucleon. In the decay energy spectrum of ^{23}O*, which was reconstructed from the measured four momenta of ^{22}O and the emitted neutron, a sharp peak was observed at $E_{\rm decay} = 48 \pm 3$ keV. This confirms the result of the previous measurement [1]. The detail setup of the present experiment was described in Ref. [2]. The measured longitudinal momentum distribution of ^{23}O* confirms the d-wave knockout character, providing a support for the J^π assignment of 5/2$^+$ for this state.

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New Modes of Nuclear Excitations for Astrophysics

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The precise knowledge of nuclear response functions plays a key role in the determination of photonuclear reactions cross sections which are of importance for the nucleosynthesis of heavier elements. In this connection information on low-energy excitations located around the neutron threshold is needed. Recently, new low-energy modes called pygmy resonances which reveal new aspects on the isospin dynamics of the nucleus have been observed. Their distinct feature is the close connection to nuclear skin oscillations which become visible in transition densities and currents [1-6].

Here, we present our theoretical approach based on density functional theory and microscopic multiphonon model [1,2] which is applied for investigations of pygmy resonances and higher-lying excitations with different multipolarities [3] in stable and exotic nuclei. The possible relation of low-energy modes to the properties of neutron or proton skins is systematically studied in isotonic and isotopic chains [1-6]. The fine structure of nuclear electric and magnetic response functions is analyzed in comparison to experimental data [2-7]. Their relevance to nuclear astrophysics is discussed.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Study of nuclei around Z=28 by large-scale shell model calculations

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We study neutron-rich nuclei in the N ~ 40 region by Monte Carlo shell model (MCSM) calculations in pfg_9d_5 shell ($0f_{7/2}$, $1p_{3/2}$, $0f_{5/2}$, $1p_{1/2}$, $0g_{9/2}$, $1d_{5/2}$). In the MCSM, a wave function is represented as a linear combination of angular-momentum- and parity-projected deformed Slater determinants. Effects of excitation across N = 40 and other gaps are important to describe properties such as deformation, and we include this effects by using the pfg_9d_5 model space. We calculate various observables of nickel and other isotopes, and study intrinsic shapes of nuclei by using quadrupole deformations of MCSM basis states before projection [1]. We discuss magicity and deformation of neutron-rich nuclei such as nickel isotopes.

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Nuclear Equation-of-State with Cluster Correlations and the Symmetry Energy

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Correlations in interacting many-body systems can lead to cluster formation, in particular to bound states and resonances. Medium modifications of clusters become increasingly important with increasing density, leading eventually to the dissolution of clusters and to the formation of a homogenous neutron-proton system. An equation-of-state, valid from low to high densities, temperatures and asymmetries, such as needed e.g. in simulations of core-collapse supernovae, has to take these effects into account. We describe this system in a quantum statistical approach (generalized Beth-Uhlenbeck approach) combined with generalized relativistic mean field concepts [1].

Such an approach also has relevance for the important question of the density and temperature dependence of the nuclear symmetry energy, since clustering effects depend strongly on the asymmetry of the system. As a consequence the symmetry energy remains finite for very low densities in contrast to mean field descriptions, where it has to go to zero. This result has been found to be consistent with experimental results of heavy ion collisions, which determined the symmetry energy at low density matter and finite temperatures [2].

In this contribution we discuss this systematic approach to an equation-of-state valid from low to high densities. We also make contact with virial expansions at low density in a generalized cluster virial expansion [3].

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Production of spin-aligned radioactive isotope beams through the dispersion-matching two-step fragmentation method

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It has been revealed that spin-oriented radioactive-isotope beams (RIBs) can be produced in the projectile-fragmentation (PF) reaction [1]. The study showed a unique relation between the spin orientation and the direction of the removed momentum of the nucleons abraded off through the reaction, suggesting that spin alignment is produce as a function of fragment momenta. Based on this technique, many nuclear moments of nuclei far from the stability line have been so far determined. However, the method also shows a drawback in the sense that the spin orientation thus produced in the PF reaction tends to be partially or completely attenuated because the fragmentation generally involves the removal of a large number of nucleons from the projectile. This is quite a non-negligible flaw with respect to the yields attainable for spin-oriented beams as high-intensity primary beams are only available for a limited set of nuclear species, and consequently in most cases rare-isotopes of interest must be produced through the removal of a large number of nucleons from the projectile. Accordingly, there has been high demand for a new technique for preventing the attenuation in spin orientation caused by large differences in mass between the projectile and the fragment.

Recently, we have made substantial progress to solve this difficult problem by developing a new method for the production of spin-aligned RIBs using the BigRIPS in-flight RI separator of the RIBF facility [2]. In the experiment, the 957-keV isomeric state in a target nucleus ^{32}Al was produced through the secondary PF of an intermediate nucleus ^{33}Al, produced in the primary PF from a ^{48}Ca beam. In this two-step PF scheme, the expected spin alignment is high since only one neutron was removed, whereas the production yield is low because of the two-fold selection with momentum slits. The loss in the yield can be minimized, when the technique of the momentum dispersion matching was combined. Direct selection of the change in momentum in the second PF can be achieved by placing a secondary target in the momentum-dispersive focal plane and a slit in the double-achromatic focal plane, because the momentum spread of the incident beam is compensated for by fulfilling the condition of momentum-dispersion matching. This method yields an intense spin-aligned RIB, while avoiding cancellation between the opposite signs of spin alignment caused by the momentum spread. In the measurement, a degree of alignment of 8(1)% was achieved for the ^{32}Al tertiary beam, which should be compared with 0.8(4)% observed in the conventional single-step PF method involving the removal of a large number of nucleons. We concluded that figure of merit, defined to be proportional to the yield and the square of the degree of alignment has been increased at least 50 times.

The presented method, realized by combining the two-step PF reaction and the dispersion matching, when applied to RIBs produced at high beam current facility, is expected to provide unprecedented opportunities for research on the nuclear structure of species situated outside the traditional region of the nuclear chart.

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Prediction of K Value for Bands in Superdeformed Regions

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Super deformation of nucleus happens after deformation stage and is defined as *"a nucleus that is very far from spherical shape forming an ellipsoidal shape with axes ratio, approximately 2:1:1"*. During nuclear super deformation(SD), energy differences occur between different bands at ground state and excited state. A super deformed nucleus is unstable and can explain the process of nuclear decay and half lives of atoms. Evidences of super deformation are obtained through gamma energy differences in different bands through spectroscopic studies. Band head energy (E_0) and band head spin(I_0) value of superdeformed(SD) bands is not known yet. Present study is aimed to evaluate the features of super deformed bands in different mass regions (A = 60, 80, 90, 130, 150,160,190) in even-even and odd-odd SD nuclei.Projection of angular momentum along the symmery axis (K) and softness parameter (σ) of selected SD nucleus were obtained through adaption of simple model equation and variable moment of inertia (VMI) model [1,2]. Simple model equation defines moment of inertia, softness parameter (σ) and gamma energies ($E\gamma$) with spin values . The VMI model equation relates lowest spin or bandhead spin(I_0) with softness parameter (σ) in terms of Mallman's energy ratio (R) in SD bands . The value of σ is taken from the Best Fit Method(BFM) of $E\gamma$ verses spin using simple model equation and R is cakculated by taking exp. Known gamma energies. We have compared our results with Shalaby's results[3] and found good agreement between two methods given in Table1. They have plotted the dynamic and static moments of inertia against the rotational frequency for different values of spin. From the figures they concluded that there is a critical spin below which the normal spin is reversed. This critical spin is to be regarded as the baseline spin or the lowest spin of the super deformed band. It is well known that for many bands such as the ground state β and γ bands, the value of K is equal to the value of the lowest spin, I_f [3]. The calculated VMI results are recently published[4].This proposed model for determination of K value or band head spin for SD bands will provide a platform for many theoreticians to find out a perfect model which could explain the features of super deformation bands in different mass regions. All the experimental data is taken from NNDC site[5].

Table 1: Comparsion of VMI results with Shalaby's results.

SD Bands	*Exp. spin	σ Value (10^{-4})	Energy ratio (R) value	K value (VMI)	K value (Shalaby's)
^{58}Ni (b1)	15	9.33	2.17	8	11
^{58}Cu	9	0.206	2.24	5	6
^{59}Cu(b1)	25/2	7.36	2.15	9.5	11.5
^{61}Zn	25/2	20.33	2.12	12.5	15.5
^{62}Zn	18	50.17	2.10	16	20
^{65}Zn	25/2	2.65	2.13	11.5	18.5
^{68}Zn	17	1.45	2.10	16	16
^{84}Zr	21	10.87	2.08	20	23
^{86}Zr	23	36.46	2.08	22	25

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Recent shell-model results for exotic nuclei

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Recent studies on exotic nuclei have been demonstrating that the shell structure far from stability is rather different from that of stable nuclei. This phenomenon is often called shell evolution. Despite rapid increase of experimental data, the shell evolution has not been fully understood yet. This is partly because experimental levels in general are not pure single-particle levels but are strongly correlated states (for a review, see [1] for instance), and partly because mechanisms causing the evolution, such as the three-nucleon force, are currently under investigation. Thus, large-scale nuclear-structure calculations and reliable theories of the effective interaction are strongly required.

In this talk, we will report on recent advancement of the description of exotic nuclei using large-scale shell-model calculations, focusing on our activities towards universal description of the shell evolution with the shell-model calculation. As for the large-scale calculation, the Monte Carlo shell model (MCSM) has been further developed recently [2], together with the conventional Lanczos diagonalization method [3]. As for the effective interaction, we have recently proposed the monopole-based universal interaction (V_{MU}) [4] for a universal description of the shell evolution. The V_{MU} works quite well also as an effective interaction for the shell model as seen, for instance, from its success in the description of a large deformation in ^{42}Si due to the tensor-force driven Jahn-Teller effect [5]. Those developments enable one to proceed to medium-heavy nuclei on the same footing. We will also pick up some very recent examples such as a systematic study of antimony isotopes from N=50 to 82 with shell-model calculations employing the V_{MU}.

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Laser-assisted decay spectroscopy of neutron-deficient Tl isotopes at CERN ISOLDE.

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One of the regions of the nuclear chart that has drawn considerable interest is that of the neutron-deficient Pb isotopes with Z ~ 82 and N ~ 104. This region exhibits a dramatic manifestation of shape coexistence.

The onset of competing proton intruder states in the odd-Tl isotopes opens the ground for complex structures at low energy leading to isomerism. A band of high-spin states was observed, built on the $9/2^-$ isomer and suggested that this was due to the odd proton occupying the $1h_{9/2}$ intruder orbital [1].
The well-established occurrence of intruder states and shape coexistence in odd-Tl isotopes, raises the question of where such states appear in the even-Tl isotopes and especially in the lightest isotopes where, based on our current knowledge, the isomeric staggering in the isotope shift is expected to disappear when going beyond N=104 to lighter nuclei.
However, the spectroscopic elucidation of such structures has proven to be highly demanding. The decay schemes are extremely complex and low-energy, highly converted transitions must be reliably identified and located in the odd-mass decay schemes. This knowledge is crucial for the measurement of charge-state distributions ($\delta\langle r^2\rangle$) through the resonant laser ionization technique.

Combining the high-sensitivity of the in-source laser spectroscopy technique and characteristic decay spectroscopy, exotic Tl isotopes (Z = 81) down to N = 98 have been studied in July 2011 with the On-Line Isotope Mass Separator ISOLDE at CERN, Geneva, Switzerland, using the Windmill detection system. Complementary decay data on isomerically purified sources were additionally collected.

The goal of these studies is to deduce ground-state and isomeric-state properties of the most neutron-deficient Tl isotopes. In this contribution, we shall report on the present status of the laser-assisted decay spectroscopy analysis of these isotopes.

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Predictions of super-heavy magic nuclei in relativistic Hartree-Fock-Bogoliubov theory

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We have explored the occurrence of the spherical shell closures for superheavy nuclei and the physics therein by using different self-consistent, covariant mean field models with density-dependent meson-nucleon couplings: the relativistic continuum Hartree-Bogoliubov (RCHB) approach [1], and the relativistic Hartree-Fock-Bogoliubov (RHFB) approach [2]. The latter method is the most elaborate model to date. The shell effects are characterized by the two-nucleon gaps $\delta_{2n(p)}$ and pairing gaps $\Delta_{\nu(\pi)}$. Although the RHFB results depend slightly on the forces used, the general set of magic numbers beyond ^{208}Pb are $Z = 120$, 138 and $N = 172$, 184, 228 and 258. Specifically our calculations are in favor of the nuclide ^{304}120 as the next spherically doubly magic nuclide. Combined with the bulk properties of symmetric matter, we find that shell effects are sensitive to the values of both scalar mass and effective mass, which essentially determine the spin-orbit effects and level density, respectively. In addition, the occurrence of shell closures is found to be essentially related to the breaking and restoration of relativistic symmetry.

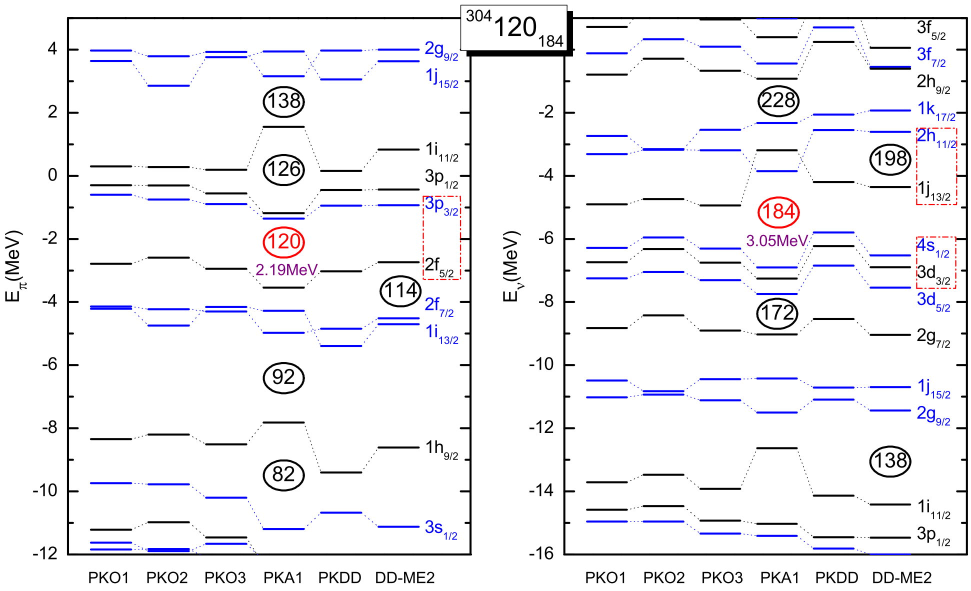

Figure 1: *Proton (left panel) and neutron (right panel) canonical single-particle spectra of super-heavy nuclide $^{304}120_{184}$. The RHFB results (PKOn, PKA1) are compared to those of RCHB (PKDD, DD-ME2). In all cases the pairing effects are calculated using the D1S force with a scaling factor f=0.9 .*

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Prompt γ-ray spectroscopy of neutron rich cadmium isotopes in the vicinity of ^{132}Sn

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Nuclei in the vicinity of ^{132}Sn have been produced by the 25-MeV proton-induced fission of a thick ^{238}U target and have been studied by in-beam, prompt γ-ray spectroscopy, using the JUROGAM-II array. This experiment has allowed new intermediate-spin states to be obtained in several neutron-rich nuclei of this region. Level schemes were produced using $\gamma - \gamma - \gamma$ coincidences, which allow clean selection and identification of cascades in the nucleus of interest. These data allow the interactions used in shell-model calculations to be tested in a region far from stability, where predictions differ. Compared to similar spontaneous-fission experiments, this reaction populates more strongly the symmetric-fission region (A=120-130) [1]. The high *N/Z* ratio of the fissioning system means that the secondary fission products remain neutron rich, even though 6 neutrons are evaporated, on average, per fission. Several new intermediate spin states have been observed and characterized by angular correlations in $^{122-124}$Cd. These results have been interpreted in terms of the shell model and comparison with theoretical calculations have shown an overall good agreement with experimental data in spite of some discrepancies for the higher spin states for which the spacing between levels are over-estimated by the shell-model calculations.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Complete E1 and spin-M1 response in nuclei from polarized proton scattering at zero degree

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Scattering of polarized protons with energies of a few 100 MeV at angles close to and including 0° has been established as a new spectroscopic tool for the study of the electric and spin-magnetic dipole response in nuclei. Complete electric dipole strenth distributions can be extracted between about 5 and 20 MeV with two independent methods based on a multipole decomposition analysis of the cross sections and the combined information from spin transfer observables. A case study of ^{208}Pb demonstrates excellent agreement with other probes but reveals the presence of previously unknown E1 strength just above the neutron threshold [1]. Furthermore, the Coulomb-nuclear interference term in the cross sections shows sensitivity to the underlying structure of E1 transitions, allowing for the first time an experimental extraction of the pygmy dipole resonance (PDR) [2].

A variety of problems are presently addressed with this new method including the first evidence for the PDR in heavy deformed nuclei, an extraction of the true low-energy E1 strength in tin isotopes [3], a test of contradictory results for gamma strength functions from different experimental methods [4,5] and a direct test of the Axel-Brink hypothesis in the region of astrophysical relevance around neutron threshold [6]. The data also provide a survey of the spin-M1 strength distributions in light and heavy nuclei including the reference case of ^{48}Ca, where a recent measurement at HIGS [7] contradicts the established result from electron scattering [8], which in turn would question the common interpretation of quenching of the spin-isospin response in nuclei [9]. The new data also serve as a crucial test of state-of-the-art nuclear structure calculations of collective modes including beyond-mean field degrees of freedom (see., e.g. Refs. [10-14]).

Work supported by the DFG under contracts SFB 634 and NE 679/3-1.

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Examining Single-Particle Structures in Neutron-Deficient Fr Isotopes via High-Resolution, Collinear Laser Spectroscopy at TRIUMF

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The region around the doubly-magic nucleus ^{208}Pb is shaped by single-particle structure [1]. This is found not only in the Pb isotopic chain but also in nearby elements. The light Po isotopes are known to deviate from this behaviour as they transition from nearly closed-shell to more mid-shell nuclei [2]. The Fr isotopic chain contains a few additional protons compared to both Pb and Po and is therefore of more proton mid-shell character.

Collinear laser spectroscopy has been the workhorse at radioactive ion beam facilities for decades to probe these nuclear properties. Information on the static electrostatic moments, the mean-squared charge radii and the spin of the nuclear state may be obtained from the atomic hyperfine structure spectrum if the lifetime of the nuclear state is sufficiently long.

The results of this study will aid further experiments in determining the Bohr-Weisskopf effect in Fr [3]. These experiments will significantly benefit from the nuclear properties determined in the collinear laser spectroscopy work during the present work.

In this contribution, preliminary results from the experiment performed at TRIUMF-ISAC probing the single-particle structure around the $N = 118$ subshell closure in the neutron-deficient Fr nuclei will be presented.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Collectivity of neutron-rich Pd isotopes close to *N* = 82

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The structure of the nuclei located in the "south" of the doubly magic nucleus ^{132}Sn (Z = 50, N = 82) is of particular interest from the point of view of nuclear physics as well as nuclear astrophysics [1]. The magicity is known to retain at ^{130}Cd (Z = 48, N = 82) [2]. Aiming at examing the magic character of N = 82 in more proton-deficient region, we have studied the low-lying states in the even-even Pd (Z = 46) isotopes close to N = 82 by using in-beam γ-ray spectroscopy method.

The experiment was performed at the RI Beam Factory operated by RIKEN Nishina Center and CNS, University of Tokyo using the BigRIPS separator [3]. Secondary cocktail beams comprising nuclei around ^{134}Sn produced by in-flight fission of a ^{238}U beam at 345 MeV/nucleon impinginged on a secondary target to induce multi-nucleon removal reactions. De-excitation γ rays were detected by the DALI2 array [4] in coincidence with reaction products of $^{122,\,124,\,126}$Pd. The first 2^+ states in $^{122,\,124,\,126}$Pd were identified for the first time. We will discuss on the N = 82 magicity based on our experimental results.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Mass measurements of short-lived nuclei at HIRFL-CSR

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With the commissioning of a newly-built Cooler Storage Ring (CSR) in the Institute of Modern Physics (IMP), Lanzhou in 2007, four campaigns of mass measurements for short-lived nuclei have been conducted using an isochronous mass spectrometry (IMS) technique. The radioactive nuclei were produced by projectile fragmentation and injected into the experimental storage ring CSRe. Revolution times of the ions stored in the CSRe were measured from which and masses of ^{78}Kr[1], ^{58}Ni[2], ^{86}Kr and ^{112}Sn fragments have been measured. Typical resolving power of ~180000 has been achieved in the experiments. The experimental results will be presented and their impact on nucleosynthesis in the rp process and nuclear structure will be discussed.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Intrinsic features of shell-model effective interaction

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The model space of shell model is highly truncated. The effect of core polarization and excitation of the valence particles into higher orbits could be absorbed through adjusting the two-body matrix elements inside the model space [1], making the interactions of shell model a difficult undertaken. Fitting to experimental spectra and binding energy is a usual strategy to settle the two-body matrix elements [2], causing the parameters of shell-model interaction strongly dependent on model spaces. With the help of spin-tensor decomposition method [3], We decompose the effective interactions in sd and pf model spaces into central force, spin-orbit force and tensor force to search the common features of these interactions and respective influences on the shell evolution.

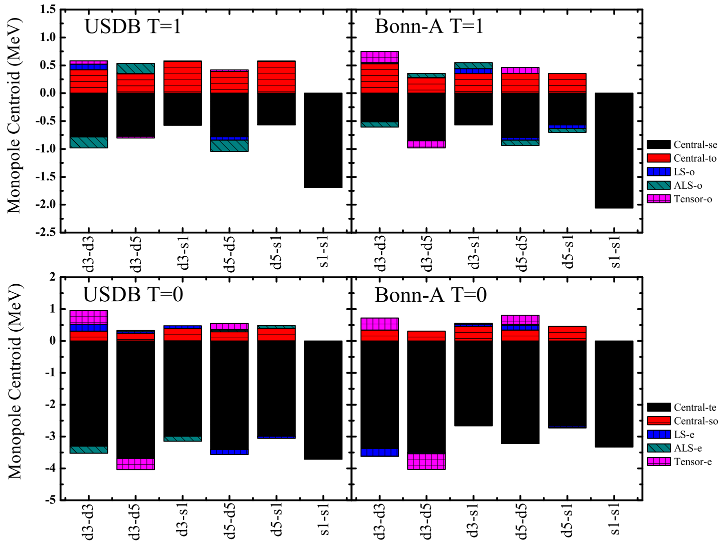

Figure 1: *Comparisons of monopole-centroid components between USDB and Bonn-A interactions decomposed by spin-tensor decomposition methods. The triplet-singlet even-odd representation is used to distinguish different channels of the interactions.*

In Fig. 1, the monopole centroids which are important in describing bulk properties such as binding energies and shell gaps [4], have been shown for Bonn-A and USDB for comparison. Imaginably, the uncertainties exist notably for the non-central forces. Through the study of configuration mixing in the structure of excited states, it has been found that the tensor force can sometimes only have a perturbation influence while spin-orbit interaction can bring a distinctive effect. Especially, the anti-symmetric spin-orbit force, which is often neglected for simplicity and could be produced by the core polarization or three-body force [5], can affect the level scheme remarkably. That may be the possible reason why the inclusion of three-body force can improve results of calculation.

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Beta-decay study of the r-process nucleosynthesis nucleus, ^{102}Rb, at TRIUMF-ISAC

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Experimental investigations of the β-decay properties of neutron-rich nuclei which lie along the astrophysical r-process [1] are becoming possible with modern RIB facilities and highly-efficient detection systems. In this experiment, a neutron-rich exotic ^{102}Rb beam was produced by 500 MeV, 10 μA protons impinging on a multilayer UC$_x$ target at the TRIUMF-ISAC facility [2]. The beam of ^{102}Rb ions was delivered to the tape-transport system at the center of the 8π spectrometer [3]. The 20 HPGe 8π γ-ray detectors were coupled with SCEPTAR, two hemispherical array of scintillators for β-tagging. This data has allowed the extension of the level scheme of ^{102}Sr [4], including the identification of the 4^+ to 2^+ transition of 285 keV. In addition the level scheme of the β-delayed neutron emission daughter nucleus, ^{101}Sr is extended and is partially in agreement with that observed in direct β-decay [5]. A near identical ground-state band structure of ^{102}Sr with $^{98,\,100}$Sr nuclei has been observed, indicating the rigidly deformed rotational nature continues towards to the $N = 66$ midshell. The current experimental measurements of ^{102}Rb β-decay half life, 25(+11-6)ms, as well as the lower limit of β-delayed neutron emission branching ratio, 54(10)%, are in disagreement with previously reported values, i.e. 37(3)ms [6], 35(+15-8)ms [7] and 18(8)% [6], respectively. The shorter β-decay half life and the significantly larger β-delayed neutron emission branching ratio have important implications for astrophysical r-process calculations, at least for the A = 101 and 102 β-decay chains.

This work is supported by NSERC (Canada). The contribution of the staff at the TRIUMF-ISAC facility is gratefully acknowledged.

A description of the experimental setup, procedures and experimental results will be presented.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Regularized multi-reference energy density functional calculations with new Skyrme parametrizations

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Symmetry restoration and configuration mixing by use of the generator coordinate method based on energy density functionals, which are referred to as a multi-reference approach, have become widely used techniques in low-energy nuclear structure [1]. Recently, it has been pointed out that these techniques are ill defined for standard Skyrme energy density functionals, and the results of multi-reference energy density functional calculations can exhibit discontinuities or even divergences in the energy when varying one of the collective coordinates. Then, a regularization procedure has been proposed to remove such spurious contributions to the energy [2]. Though recent Skyrme parametrizations employ non-integer powers of the density for the density-dependent terms in energy density functionals for a realistic incompressibility of symmetric infinite nuclear matter, this regularization procedure imposes integer powers of the density for these terms. At present, only dated parametrizations fulfill this condition. Therefore, we have constructed new Skyrme parametrizations [3] for multi-reference energy density functional calculations with the regularization procedure using the state-of-the-art fitting protocols. Compared to the widely used SLy5 and to the SIII that has integer powers of the density for the density-dependent terms, a significant improvement of the reproduction of the experimental binding energies and charge radii for a wide range of singly magic nuclei is observed [3].

In this contribution, we will report the results of regularized multi-reference energy density functional calculations for Mg isotopes with our new Skyrme parametrizations. Our method consists of constrained Hartree-Fock-Bogoliubov (HFB) for different quadrupole moments as a generator coordinate, particle-number and angular-momentum projections for each HFB state, and configuration mixing of the projected states by the generator coordinate method. We will show how the regularization removes the spurious contributions to the energy. We will discuss the spectroscopic properties of Mg isotopes, such as their isotopic shift and energy spectra.

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Centrifugal stretching of ^{170}Hf in the Interacting Boson Model

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The prediction of spectra of deformed nuclei remains a challenge to microscopic models, and requires the input of collective models. Common approaches are geometric models characterizing the deformed nucleus by the well-known β- and γ-deformation parameters. Such models typically assume rigid deformations. Using the Bohr Hamiltonian [1] allows the introduction of soft potentials, as for example in the critical point solution X(5) [2], which in turn allow for vibrations. Another approach is offered by bosonic models, especially the interacting boson model (IBM) [3], which is capable to describe a large variety of nuclear structure, including vibrators [within the algebraic U(5) limit], axially-symmetric rotors [corresponding to SU(3) symmetry], and γ-soft rotors [O(6) symmetry]. More importantly, the model allows interpolation between those symmetries, giving access to the description of the spectra and electro-magnetic properties of a wide range of transitional nuclei. A feature of the model is its valence character - only nucleons in the valence space are considered, hence the number of available valence bosons (pairs of nucleons) is limited to $N < 20$ near mid-shell in the case of the rare-earth region, where typically axially-symmetric rotors are found.

Intrinsic excitations, that is vibrations such as the γ-vibrational and the $0^+_{K=0}$ band heads in rotational nuclei, are valence excitations and are well described within the IBM. A problem, however, is the reproduction of electromagnetic properties within a rotational band. New results from a recent plunger experiment on ^{170}Hf at WNSL [4] displays rising transitional quadrupole moments Q_t, similar to previous data on ^{168}Hf [5]. This effect of centrifugal stretching of the nucleus is also predicted within the confined β-soft (CBS) rotor model [6,7]. A standard IBM calculation with $N = 13$ bosons, however, shows a dramatic drop of Q_t values with increasing spin. Large-N calculation within the IBM can resolve this problem, however, at the expense of the description of intrinsic excitations. We suggest a simple procedure to obtain a simultaneous description of electromagnetic properties and energies within the ground state band of deformed nuclei, and their intrinsic excitations, demonstrated in the example of ^{170}Hf.

This work is supported by U.S. DOE under Grant No. DE-FG02-91ER-40609.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Core excitations across the neutron shell gap in the Z=81 ^{207}Tl nucleus

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Deep-inelastic collisions of a ^{208}Pb beam on a ^{208}Pb target were performed using the ATLAS accelerator at Argonne National Laboratory. A natural pulsing of the beam occurs due to the fundamental frequency of the bunching system; some of these beam pulses may be deflected, leading to the possibility of detecting cross-isomer coincidences with a lifetime of ∼800 ns. The GAMMASPHERE detector array was used for the detection of prompt and delayed gamma-rays in the reaction products.

^{207}Tl is one proton away from the ^{208}Pb doubly-magic nucleus. Its low-energy level structure is dominated by the single proton-hole states $\pi s_{1/2}^{-1}$, $\pi d_{3/2}^{-1}$, and $\pi h_{11/2}^{-1}$. The $11/2^-$ state is isomeric with $T_{1/2}$= 1.33(11) s [1]. To get to levels higher in excitation than this isomeric state, the neutron core must be broken.

The reaction partner of ^{207}Tl is ^{209}Bi, which has a relatively well established level scheme compared to ^{207}Tl [1,2]. Cross-coincidences between these two nuclei were used to confirm or establish levels above the $11/2^-$ isomeric state in ^{207}Tl, which was previously the highest confirmed spin state [1]. The level scheme has been expanded to a spin of approximately 45/2. Tentative multipolarities have been assigned to some transitions, based on intensity balances. Branching ratios have also been determined. Additionally, shell-model calculations have been performed. By comparing the theoretical and experimental level schemes, information about the configurations of individual states was obtained.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Single-particle structure of neutron-rich N=40 isotopes

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The region around neutron-rich $N = 40$ nuclei has recently attracted a lot of interest. The high-lying 2^+ state in ^{68}Ni and its small transition probability to the ground state are a result of the $N = 40$ harmonic oscillator shell gap between the fp shell and the $1g_{9/2}$ orbital. This shell gap is reduced for the more neutron rich Fe and Cr isotopes; both the $N = 40$ isotones ^{66}Fe and ^{64}Cr show a decreased energy of the first 2^+ state and increased transition probability $B(E2;\ 2^+_1 \rightarrow 0^+_{gs})$. The collective behavior is caused by quadrupole correlations which favor energetically the deformed intruder states from the neutron $\nu g_{9/2}$ and $\nu d_{5/2}$ orbitals. In the shell model the increase in $B(E2)$ values and the decrease in 2^+ excitation energy can be reproduced if the neutron $\nu g_{9/2}$ and $\nu d_{5/2}$ intruder orbitals are included in the model space [1].

Spectroscopic studies of neutron-rich nuclei around $N = 40$ have been performed at NSCL utilizing the S800 spectrometer and the GRETINA gamma detector array. The study focused on the one-neutron removal reactions from ^{68}Ni and ^{64,66}Fe. The longitudinal momentum distribution of reaction residues indicates the angular momentum of the removed nucleon, and spectroscopic factors can be extracted from the measured cross section for the population of individual states in the odd-mass residual nucleus. An experimental challenge in this region of the nuclear chart is the occurrence of low-lying isomeric states resulting from the neutron $\nu g_{9/2}$ intruder orbital. This experiment employs a new technique of combined prompt and delayed γ-spectroscopy using the GRETINA Germanium array to detect prompt transitions at the target position and the CsI(Na) hodoscope array at the end of the focal plane detector box of the S800 spectrograph to tag the population of an isomeric state. This approach allows to quantify the occupancy of the intruder neutron $\nu g_{9/2}$ and $\nu d_{5/2}$ orbitals in ^{68}Ni and ^{64,66}Fe.

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New studies on the aspects of nuclear shapes

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We have employed various models to study nuclear deformations and incurred effects on the structures of nuclei. The investigation based on the Woods-Saxon potential with the inclusion of high-order deformations shows that the multipolarity-six (β_6) deformation plays an important role in superheavy mass region [1, 2]. The β_6 deformation leads to the enlarged $Z = 100$ and $N = 152$ deformed shell gaps, which increases the stabilities of superheavy nuclei. The β_6 deformation can well explain the delayed rotational alignments observed in even-even superheavy nuclei with $N \geq 152$ (compared with the alignments with $N < 150$) [2]. The configuration-constrained PES calculations with the inclusion of the β_6 deformation can remarkably improve the calculations of excitation energies of the observed isomeric states [1].

We have used the angular-momentum-projection method to improve the potential-energy-surface (PES) calculation, obtaining spin-conserved PES [3]. The spin-zero PES can well reproduce the first and second minima, inner and outer barriers (fission barrier), and also isomeric states for actinide nuclei in which the experimental data have been available. It is striking that experimental information gives deformed shapes for Fe and Cr isotopes with neutron numbers near 28 (neutron shell closure) or 40 (semi-shell closure). This unusual observation can be well reproduced by the present angular-momentum-projected PES calculations, while usual mean-field models without angular momentum projection give nearly spherical shapes for these Fe and Cr isotopes. The angular-momentum-projected PES calculations for neutron-deficient Hg and Pb isotopes show that the consideration of the self-consistent deformation evolution is crucial to give the right description of rotational states, while the usual projected shell model was performed with fixing deformation.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

β-decay studies of neutron-rich nuclei in the vicinity of ^{78}Ni

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Studies of β-decay properties including half lives measurements as well as investigations on β-delayed γ-ray spectroscopy in neutron-rich nuclei are of great interests not only for nuclear physics but also for astrophysics. It serves as a good testing ground for various applications and theories that try to understand and predict the changing of shell structure as one moves farther from stability toward the neutron drip-line.

Rcecently, an experiment aiming at studying nuclei around doubly magic ^{78}Ni has been performed as EURICA campaign at RIBF, RIKEN. A highly segmented silicon stopper named as WAS3ABi DSSD array is mounted at F11 focal plain of ZeroDegree spectrometer, surrounded by EUROBALL γ-ray detectors array, which consists of 12 germanium clusters. Nuclear structure around ^{78}Ni were studied via β-decay of very neutron-rich nuclei in the vicinity of ^{78}Ni produced by inflight fission of a 345-MeV/nucleon ^{238}U beam at RIBF. The β-decay measurements were realized by performing timing-position correlation between implanted heavy ions and β-particles. With the help of the high beam intensity at RIBF, many new half lives were measured: half lives of ^{76}Co, ^{79}Ni, ^{81}Cu, ^{84}Zn, ^{86}Ga, ^{88}Ge and so on, have been measured for the first time. Also, nuclei such as ^{78}Ni, which have been measured in previous experiment but resulted in a large error bar, are re-measured in this campaign with much higher statistics. The new half lives coming from the experiment allow for systematic studies and comparisons of different mass models and theoretical calculations around ^{78}Ni.

On the other hand, taking advantage of the high effciency of the EUROBALL γ-ray detectors array, β-delayed spectroscopy have also been studied in details. β-γ as well as β-γ-γ decay spectrum of nuclide along Ni isotope-chain have been taken from the experiment. It is of great importance to study the low-lying states of odd Cu isotopes as states with large collectivities as well as strong monopole migration effect were observed experimentally in odd-mass Cu nuclides at $N > 40$, which manifest a strong evidence of shell erosion at $Z = 28$ in this mass region. Level schemes of odd Cu isotopes built from the new data set will largely extends present knowledge of the evolution of the nuclear shell structure approaching doubly magic ^{78}Ni. Some of the results will be summarized and reported in this presentaion.

International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Level Lifetimes in ^{94}Zr from DSAM Measurements following Inelastic Neutron Scattering

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Inelastic neutron scattering (INS) with the detection of emitted γ rays, *i.e.,* the (n,n′γ) reaction, has been utilized at the University of Kentucky Accelerator Laboratory for many years to study the detailed structure of stable nuclei [1]. Through γ-ray excitation function, γ-ray angular distribution, and γ-γ coincidence measurements, level schemes of the low-spin states of stable nuclei can be established, and the Doppler-shift attenuation method (DSAM) can be utilized to determine the lifetimes of excited nuclear states [2]. Moreover, DSAM-INS measurements frequently yield lifetimes for states that are not populated with other reactions. For example, without the lifetimes of non-yrast 2^+ and 4^+ states in ^{94}Zr, novel collective structure, which provided new insights into shape coexistence and the role of subshells in nuclear collectivity, would have otherwise gone unnoticed [3]. This work also exposed that the chemical properties of the scattering samples used in DSAM-INS lifetime measurements must be understood and led to the resolution of a nuclear structure anomaly [4].

Several years ago, our group performed ^{94}Zr(n,n′γ) measurements with an enriched ^{94}ZrO$_2$ scattering sample. Based on the observation that the 752.5-keV transition from the second 2^+ state at 1671.4 keV to the first excited state at 918.8 keV exhibits a large $B(M1;2_2^+\rightarrow 2_1^+)$, we identified the second 2^+ state as the lowest mixed-symmetry state [4]. In addition, these measurements of ^{94}Zr revealed anomalous behavior unobserved in other nuclei; the B(E2) value for the transition from the second excited 2^+ state to the ground state was found to be larger than that from the first 2^+ state to the ground state. This nucleus thus emerged as the lone example of an inversion of the B(E2) strengths for the lowest-lying 2^+ excitations.

As questions have been raised about this anomaly, we carried out additional (n,n′γ) measurements using metallic Zr, ZrO$_2$, and Zr(OH)$_4$ samples of natural isotopic composition [5]. The lifetime of the second 2^+ state was redetermined by DSAM, and a new value for $B(E2;2_2^+\rightarrow 0_1^+)$ was obtained. The results differ significantly from the previously published values [4], with the new B(E2) found to be roughly half of the previous value and slightly less than $B(E2;2_1^+\rightarrow 0_1^+)$. A reanalysis of the original γ-ray data from the enriched ^{94}ZrO$_2$ sample failed to expose the source of this discrepancy; however, powder x-ray diffraction and scanning electron microscopy performed on each scattering sample, including the enriched scattering sample used previously, provide clues to an explanation and reveal the role of the chemical properties of the sample material in DSAM lifetime determinations.

This material is based upon work supported by the U. S. National Science Foundation under Grant No. PHY-0956310.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

A new experimental study of the 12Be cluster structure

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Neutron rich Beryllium isotopes have attracted much attention for their cluster or molecule structures at excited (resonant) states [1]. Experimentally one novel method, the inelastic excitation followed by coincidently recording the decay products, was applied to probe the molecule resonant states [2, 3]. But so far, the experimental results for ^{12}Be seem quite controversial. Freer et al reported the observation of molecule resonant states in ^{6}He+^{6}He channel and ^{8}He+^{4}He channel [2]. However, most of these resonances were not identified in a similar experiment carried out later on by Charity et al [3].

We have therefore carried out a new experiment with ^{12}Be secondary beam at 31.3MeV/u provided by HIRFL-RIBLL facility in Lanzhou. Two charged fragments produced from the breakup of ^{12}Be on a Carbon target were coincidently recorded by a down-stream zero-degree telescope consisting of a 300um-thick double-sided silicon strip detector (DSSD) and a 4*4 CsI scintillator array. Typical particle identification performance for coincidently measured Helium fragments is shown in Fig.1. The molecule resonant states were reconstructed from 4He+8He and ^{6}He+^{6}He decaying channels. These states agree well with previously reported results by Freer et al.[2], and therefore support the highly clustering structure of ^{12}Be. Cross sections for these two breakup channels were also deduced.

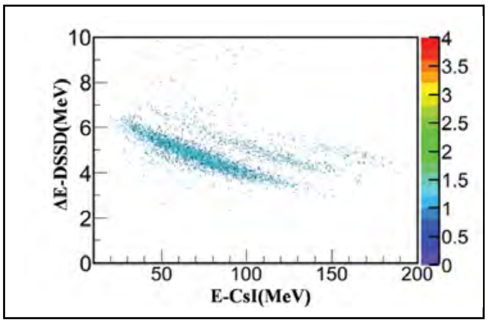

Figure 1: Coincidently measured Helium fragments resulted from the inelastic excitation and decay of the ^{12}Be nucleus. The bands starting from the bottom are for 4He, 6He and 8He, respectively.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Observation of new isomers in neutron-rich Tb isotopes

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The region of lanthanide isotopes around $N = 90$ is one of the most well-known examples of nuclear shape transition from spherical to prolate deformed shape. It is interesting to know how the shape does change in further neutron-rich nuclei. It is expected that the deformation may proceed toward the double mid-shell region between $N = 82, 126$ and $Z = 50, 82$ shell closure. However, little has been known about the excited states of nuclei far from stability line such as $N \sim 100$ in this region.

We have studied excited states of such neutron-rich isotopes by means of delayed γ-ray spectroscopy at the RIKEN RI Beam Factory. These isotopes were produced by in-flight fission of 345MeV/nucleon ^{238}U. Fission fragments were separated and identified by using the in-flight separator BigRIPS[2]. Particle identification was made event-by-event by measuring the magnetic rigidity ($B\rho$), time of flight (TOF) and the energy loss (ΔE). Delayed gamma-rays from stopped beams were detected by four clover-type germanium detectors by the particle γ slow correlation technique.

We have observed new isomers systematically in the terbium isotopes, ^{165}Tb, ^{166}Tb, ^{167}Tb and ^{168}Tb. Half-lives, γ-ray energies and γ-ray relative intensities of these isomers have been obtained. Level schemes are constructed for the first time for these nuclei. We interpret that the isomeric states of ^{165}Tb and ^{167}Tb are characterized by one quasi-proton excitation to the Nilsson orbit of π7/2[523] or π9/2[404]. In this presentation, the evolution of nuclear shape and shell structure along the terbium isotopes will be discussed from the systematic comparisons of the quasi-proton states and the moment of inertia of the ground state bands obtained in this study.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Spins, Electromagnetic Moments, and Isomers of $^{100\text{-}130}$Cd

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We report on the first study of cadmium by high-resolution laser spectroscopy. Nuclear spins, electromagnetic moments and rms charge radii of ground and isomeric states have been determined along the chain, approaching N=50 and ultimately reaching N=82. These experimental data provide a solid basis for improving the nuclear-structure understanding in the vicinities of the doubly magic ^{100}Sn and ^{132}Sn. Specific questions, for instance the deformation of the cadmium isotopes, can now be resolved.

The measurements were carried out with the collinear laser spectroscopy setup at ISOLDE-CERN. Deep-UV excitation at 214.5 nm and radioactive-beam bunching delivered the necessary experimental sensitivity. Such establishment of UV laser beams could potentially provide access to isotopic chains thus far unstudied due to demanding atomic transitions.

Long-lived isomers have been observed in ^{127}Cd and ^{129}Cd for the first time. The data reveal the relative degree of collectivity between ground and isomeric states, not only from their quadrupole moments, but through their charge radii as well. Moreover, one essential feature of the spherical shell model is unambiguously confirmed by a linear increase of the $11/2^-$ quadrupole moments. Remarkably, this mechanism is found to act well beyond the $h_{11/2}$ shell.

In this contribution the experimental results and their preliminary interpretation will be presented in the context of the shell structure in the vicinity of Z=50 and its evolution towards the neutron 50 and 82 shell closures.

Density profiles of light nuclei in Monte Carlo shell-model calculation

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In light nuclei, the α cluster structure has an important role around the α breakup threshold region. Nevertheless, the shell-model picture which is considered to be the essential configuration in nuclei has difficulty to discuss the state which appears around the threshold region so far. One of the reason is that the cluster configuration is not properly taken into the model space in the usual shell-model calculation. This difficulty might be overcome by taking large number of shell orbit with the most recent parallel computer. Here, we use Monte Carlo shell-model (MCSM) [1,2,3] to determine the wavefunction accurately. To specify whether the state really has the cluster structure (such as α) is also difficult. Because the method is not established to see the intrinsic frame which corresponds to the body-fixed coordinate of the system. Therefore, we define the intrinsic state of the MCSM wavefunction, Φ^{intr} as follows.

$$|\Phi^{intr}\rangle = \sum_n f_n R(\Omega_n)|\phi_n\rangle$$

Here, $R(\Omega_n)$ shows the rotation operator which aligns the principal axis to z-axis for each Slater determinant, $|\phi_n\rangle$.

We discuss the cluster configuration of light nuclei by using the intrinsic state. Here, we focus on the neck shape of intrinsic state of the ^{8}Be ground state. The importance to perform alignment for each Slater determinant to obtain the intrinsic state is discussed. The density before alignment has vague two α structure. On the other hand, the clearer two α's structure in the intrinsic density has been found. This shape of ^{8}Be is consistent with the result of the other recent *ab-initio* calculation such as Green's function Monte Carlo. The ground state properties of other nuclei such as ^{6}He and Be isotopes have been discussed and the similar analyses have been performed.

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Cluster Structure of Light Nuclei via Relativistic Dissociation in Nuclear Track Emulsion

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The capabilities of relativistic nuclear physics for the development of the physics of nuclear clusters are overviewed [1]. Nuclear track emulsion continues to be an effective technique that allows one to study the cluster dissociation of a wide variety of light relativistic nuclei within a common approach. Despite the fact that the capabilities of the relativistic fragmentation for the study of nuclear clustering were recognized quite a long time ago, electronic experiments have not been able to come closer to an integrated analysis of ensembles of relativistic fragments. The continued pause in the investigation of the “fine” structure of relativistic fragmentation has led to resumption of regular exposures of nuclear emulsions in beams of light nuclei produced for the first time at the Nuclotron of the Joint Institute for Nuclear Research (JINR, Dubna). To date, an analysis of the peripheral interactions of relativistic isotopes of beryllium, boron, carbon and nitrogen, including radioactive ones, with nuclei of the emulsion composition, has been performed, which allows the clustering pattern to be presented for a whole family of light nuclei.

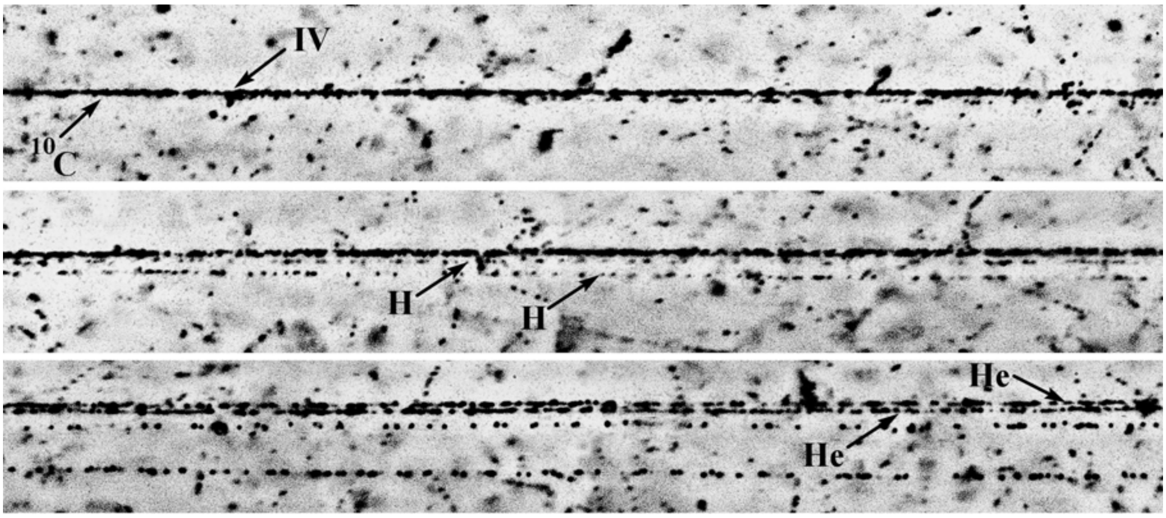

Figure 1: *Subsequently photographed event of coherent dissociation $^{10}C(1.2A\ GeV) \rightarrow {}^{9}B_{g.s.} + p$ in nuclear track emulsion.*

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International Nuclear Physics Conference INPC2013: 2-7 June 2013, Firenze, Italy

Nuclear magnetic and antimagnetic rotation in covariant density functional theory

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In the past decades, the experimental discovery of the rotational-like sequences in near-spherical nuclei, which are known as magnetic rotation or antimagnetic rotation bands, has opened a new era in high-spin physics. The intriguing feature here is that the orientation of the rotor is not specified by the deformation of the overall density distribution but rather by the current distribution induced by specific nucleons moving in high-j orbitals [1].

The cranking mean field approaches are widely used to understand the structure of the rotational bands in nuclei. A description of the magnetic rotation band requires a model going beyond the principal axis cranking, i.e., the rotational axis does not coincide with any principal axis of the density distribution. This leads to the development of the tilted axis cranking approach within the framework of the pairing plus quadrupole model or the Strutinsky shell correction method [1].

The covariant density functional theory with a small number of parameters allows a very successful description of ground-state properties of nuclei all over the nuclear chart. Recently, the self-consistent tilted axis cranking covariant density functional theory has been established in Ref. [2] based on a newly developed point-coupling interaction PC-PK1 [3]. So far, this model has been applied successfully to investigate magnetic rotation in both light nuclei such as ^{60}Ni [2] and heavy nuclei such as ^{198,199}Pb [4]. Moreover, it provides a fully self-consistent and microscopic investigation for the observed antimagnetic rotation band in ^{105}Cd [5,6].

In Ref. [2], the observed four magnetic rotation bands in ^{60}Ni are investigated systematically. The tilted angles, deformation parameters, energy spectra, and reduced $M1$ and $E2$ transition probabilities have been studied in a fully microscopic and self-consistent way for various configurations. It is found that there is a transition from magnetic rotation to electric rotation with the increasing angular momentum.

In Refs. [5,6], the observed antimagnetic rotation band in ^{105}Cd is investigated. The experimental spectrum as well as the $B(E2)$ values are reproduced very well. This microscopic investigation gives a strong hint that antimagnetic rotation with its two "shears-like" mechanisms is realized in specific bands in nuclei.

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