

COLLABORATION AGREEMENT

IN2P3 - COPIN

I. Identification of the laboratories

Partner	COPIN
IN2P3 laboratories	IPHC
Partner laboratories	Cracovie (IFJ PAN)

II. Identification of the collaboration

Title of the collaboration	Statistical effects in nuclei and nuclear Jacobi shape transitions
Number of the collaboration	05-119
IN2P3 spokesperson	J. DUDEK
COPIN spokesperson	A. MAJ
Scientific Domain	Nuclear Physics

Status of the collaboration

Status	The collaboration shall end on December 31st, 2022
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III. Status report for the period January 1st to December 31st, 2022

III.1 IN2P3 scientists in COPIN

Total time approved for 2022	20
Total time used for 2022	20
List of scientists	1. J.Dudek (14 days) 2. D.Curien (6 days)

III.2 COPIN scientists in France

Total time approved for 2022	20
Total time used for 2022	20
List of scientists	1. A.Maj (6 days) 2. I.Dedes (14 days)

III.3 Scientific results of the above-mentioned collaboration

Description	
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Thanks to the installation of the powerful nuclear structure theory computer programs optimised for several sub-fields of nuclear structure we were able to advance with several projects; here we will mention first of all those which either gave publications or have been submitted for publication this

year. These projects complete our efforts to establish a firm basis for the studies of new exotic symmetries and exotic configurations in particular in exotic nuclei.

A) To start, thanks to the large scale total energy calculations we were able to establish for the first time the presence of what is referred to as 4-fold (or universal octupole) neutron magic number $N=136$. It is manifested by the presence of the strong shell-gap openings in all 4 octupole deformation degrees of freedom, α_{30} (standard pear shape octupole) as well as the exotic ones, α_{31} , α_{32} (the latter representing tetrahedral symmetry) and finally the α_{33} deformation.

B) We found out that thanks to the universal magic gap openings, several nuclei in the vicinity of ^{208}Pb (but heavier than the doubly magic $Z=82$ $N=126$ one) lose their spherical symmetry with increasing neutron number not acquiring the usual quadrupole deformation, but rather one of the octupole deformations.

This brings us to the issue of the exotic molecular symmetries manifested in sub-atomic (nuclear) physics. Indeed, the α_{31} octupole deformation leads to nuclei with the C_{2v} symmetry, the α_{32} to the T_d or D_{2d} symmetries and the α_{33} deformation to the D_{3h} point-group symmetry. Related results will be published in refs. [3] and [4].

C) Using point group representation theory we were able to establish the experimental identification criteria for all the mentioned exotic symmetries. These results were published in ref. [1]

D) In analogy to the four-fold magic number $N=136$ we found another one, $N=196$, applying to the super-heavy nuclei. There the manifestations of the exotic symmetries appeared originally un-expected to us. It turned out that the realistic calculations predict the presence of what we call “archipelago of D_{3h} symmetry” in the form of three islands with combination of the negative (oblate shape) quadrupole components α_{20} and simultaneously significant α_{33} octupole shapes. The islands correspond to: “normal” deformed D_{3h} nuclei with $\alpha_{20} \sim -0.25$, to super-deformed D_{3h} oblate nuclei with $\alpha_{20} \sim -0.50$ and to hyper-deformed oblate D_{3h} nuclei with $\alpha_{20} \sim -0.90$. These results were submitted for publication, ref. [3].

E) Finally we have performed the intensive calculations of the isomer properties in light nuclei corresponding to what is called $N=40$ island of inversion. We were able to compare with success our predictions with experiments obtained with the colleagues working on the mass separators at GSI Darmstadt Germany and TRIUMF/TITAN Facilities, Canada, common publication in PRC Letters, ref. [2]

In conclusion:

We believe that our collaboration has accomplished a number of tasks, which we were focussing on during a few years of our collaboration and prepared in this way a starting point for the new project which will be presented this year.

Publications (October 2021 - October 2022)

1) J. Yang, J. Dudek, I. Dedes, A. Baran, D. Curien, A. Gaamouci, A. Gozdz, A. Pedrak, D. Rouvel, H. L. Wang, and J. Burkat;

Exotic shape symmetries around the fourfold octupole magic number $N = 136$:

Formulation of experimental identification criteria;

PHYSICAL REVIEW C 105, 034348 (2022)

2) W. S. Porter, B. Ashrafkhani, J. Bergmann, C. Brown, T. Brunner, J. D. Cardona, D. Curien, I. Dedes, T. Dickel,

J. Dudek, E. Dunling, G. Gwinner, Z. Hockenbery, J. D. Holt, C. Hornung, C. Izzo, A. Jacobs, A. Javaji, B. Kootte,

G. Kripko-Koncz, E. M. Lykiardopoulou, T. Miyagi, I. Mukul, T. Murbock, W. R. Plaß, M. P. Reiter, J. Ringuette,

C. Scheidenberger, R. Silwal, C. Walls, H. L. Wang, Y. Wang, J. Yang, J. Dilling, and A. A. Kwiatkowski

Mapping the $N = 40$ island of inversion: Precision mass measurements of neutron-rich Fe isotopes;

PHYSICAL REVIEW C 105, Letter, L041301 (2022)

3) J. Yang, J. Dudek, I. Dedes, A. Baran, D. Curien, A. Gaamouci, A. Gózdź, A. Pédra, D. Rouvel,

and H. L. Wang,

Exotic Symmetries as Stabilizing Factors for Super-Heavy Nuclei:

Symmetry Oriented Generalized Concept of Nuclear Magic Numbers;

PHYSICAL REVIEW C, accepted

4) J. Yang, J. Dudek, I. Dedes, A. Baran, D. Curien, A. Gaamouci, A. Gózdź, A. Pédra, D. Rouvel,

and H. L. Wang,

Islands of Oblate Hyper-deformed and Super-deformed Super-heavy Nuclei with D_{3h} Point Group Symmetry in Competition with Normal-deformed D_{3h} States: Archipelago of D_{3h} -Symmetry Islands;

PHYSICAL REVIEW C, submitted

5) I. Dedes and J. Dudek

Unprecedented 7th-Order multipole components in nuclear equilibrium deformations induced by tetrahedral symmetry;

PHYSICAL REVIEW LETTERS, submitted

Conference Presentations (October 2021 - October 2022)

1) I. Dedes

Experimental identification criteria of molecular symmetries in nuclei around octupole magic number $N=136$

Invited talk,

International Conference on Shapes and Symmetries: From Experiment to Theory (SSNET 22, Paris area)

2) J. Dudek

New Directions in Nuclear Spectroscopy: Research of Exotic Point-Group Symmetries;

Invited talk,

Thirty Ninth International Workshop on Nuclear Theory, IWNT39-2022, Rila Mountains, Bulgaria

3) J. Dudek

From Exotic Symmetries to Isomers in Stable and Exotic Nuclei;

Invited talk,

100 Years of Nuclear Isomers — EMMI Workshop, Berlin 2022

4) M. Ciemala

Feeding of the isomers of different deformations via GDR gamma decay studied with nuBall + PARIS;

Invited talk

Zakopane Conference on Nuclear Physics “Extremes of the Nuclear Landscape”, Zakopane, 2022

5) A. Maj

A quest for nuclear Jacobi shapes: the impact of Bent Herskind on theory and instrumentation development;

Invited talk, SSNET 22

(International Conference on Shapes and Symmetries: From Experiment to Theory) Paris area, 2022

6) P. Bednarczyk

Studies of rotational features and search for new exotic shapes of nuclei close to ^{40}Ca :

Status and prospects of experiments;

Invited talk

28th Nuclear Physics Workshop - Collective Excitations, Kazimierz Dolny, 2022

Experiment proposals

1) GANIL: Identification of exotic reaction channels in $^{238}\text{U}+^{238}\text{U}$;

D. Ackermann, S. Heinz, A. Andreyev, B. Andel, S. Antalic, P. Bednarczyk, D. Boilley, L. Caceres, A. Chbihi, P. Chowdhury, E. Clement, M. Caamaño, L. Corradi, Z. Favier, G. De France, P. Delahaye, H.M. Devaraja, O. Dorvaux, A. Drouart, J. Dudek, E. Fioretto, J. Frankland, B. Gall, F. Galtarossa, K. Hauschild, D. Hinde, I. Itkis, A. Karpov, B. Kindler, F. Kondev, A. Korichi, E. Kozulin, G. Knyazheva, A. Lemasson, M. Lewitowicz, B. Lommel, A.

Lopez-Martens, A. Maj, T. Mijatovic, A. Mistry, G. Montagnoli, P. Mosat, Y. Nagame, K. Nishio, K. Novikov, R. Orlandi, I. Pchelintsev, J. Piot, Z. Podoliak, D. Ramos, P. Regan, P. Reiter, M. Rejmund, V. Saiko, H. Savajols, G. Scamps, D. Seweryniak, C. Simenel, G.I. Stefan, A.M. Stefanini, J. Steiner, Ch. Stodel, L. Stuttge, B. Sulignano, S. Szilner, O. Tarasov, Ch. Theisen, M. Vandebrout, P.M. Walker.

Experiment was performed in GANIL in 2022, Data are being analyzed.

2) GANIL: Pygmy dipole resonance in ^{140}Ce using the $(n,n'\gamma)$ reaction at NFS;

M. Vanderbrouck, A. Maj, M. Ciemala, M. Kmiecik et al.,

Experiment was performed in GANIL in 2022, Data are being analyzed.

3) Links between ^{80}Sr compound nucleus shape and its residue's deformation studied with the GDR;

M. Ciemala, M. Kmiecik, A. Maj, B. Fornal, P. Bednarczyk, I. Dedes, K. Mazurek, J. Dudek et al.

Experiment is scheduled to be performed in IJCLab Orsay mid-November 2022

4) Investigation of high spin structures in ^{44}Ti and ^{42}Ca via discrete and continuum gamma spectroscopy using nuBall2, PARIS and OPISA setup;

M. Matejska-Minda, P. Bednarczyk, I. Dedes, A. Maj, M. Ciemala, B. Fornal, J. Dudek et al.,

Experiment will be performed most probably in 2023

5) Onset of deformation in A~40 region - nuclear shapes in ^{44}Ti ;

K. Hadynska-Klek, (A. Maj, P. Bednarczyk, M. Kmiecik, M. Ciemala, B. Fornal) et al.,

Experiment will be performed most probably in 2023

Experiments 6 and 7 were suspended as the main detector, CORSET, belongs to Dubna group, and Dubna and other Russian institutions are excluded from the European experiments.

Comment Validation	
Unity Director	Sandrine COURTIN (IPHC) - 2022-10-13 16:17:01