Final Scientific/Technical Report

U. S. Department of Energy. Office of Science

DOE Award number: DE-FG02-07ER41459

Project title: "Nuclei at extreme conditions: A relativistic study"

Name of Principal Investigator: Prof. Anatoli Afanasjev

Recipient Organization: Mississippi State University

Recipient Identifying Number or Account Number: 362990

Project/Grant period: 12/15/2006 - 11/14/2014
with no cost extension till 11/14/2015

1 Executive summary

The major goals of the current project were further development of covariant density functional theory (CDFT), better understanding of its features, its application to different nuclear structure and nuclear astrophysics phenomena and training of graduate and undergraduate students.

The investigations have proceeded in a number of directions which are discussed in detail in the part “Accomplishments” of this report. We have studied the role of isovector and isoscalar proton-neutron pairings in rotating nuclei; based on available experimental data it was concluded that there are no evidences for the existence of isoscalar proton-neutron pairing. Generalized theoretical approach has been developed for pycnonuclear reaction rates in the crust of neutron stars and interior of white dwarfs. Using this approach, extensive database for considerable number of pycnonuclear reactions involving stable and neutron-rich light nuclei has been created; it can be used in future for the study of various nuclear burning phenomena in different environments. Time-odd mean fields and their manifestations in terminating states, non-rotating and rotating nuclei have been studied in the framework of covariant density functional theory. Contrary to non-relativistic density functional theories these fields, which are important for a proper description of nuclear systems with broken time-reversal symmetry, are uniquely defined in the CDFT framework. Hyperdeformed nuclear shapes (with semi-axis ratio 2.5:1 and larger) have been studied in the $Z = 40 - 58$ part of nuclear chart. We strongly believe that such shapes could be studied experimentally in the future with full scale GRETA detector.

Significant efforts were dedicated to a microscopic understanding of single-particle and collective phenomena and their interplay in the CDFT framework. Deformed one-quasiparticle states have been systematically studied in the actinides. The dynamics of nuclear single-particle motion and its coupling with collective vibrations have been investigated in odd-mass spherical nuclei within the covariant theory of particle-vibration coupling; the accounting of this coupling substantially improves the description of experimental data. These investigations have addressed the spectroscopic quality of the CDFT. Collective phenomena are represented by fission and collective rotation. The impact of pairing, triaxiality and octupole deformation on fission barriers in actinides and superheavy nuclei have been studied in detail. The experimental data on fission in actinides are well described in the calculations. The rotation of actinides have been successfully reproduced in the cranked relativistic Hartree-Bogoliubov framework; the level of accuracy of the reproduction of experimental data exceeds that of more phenomenological approaches.

For the first time, the global assessment of the performance of covariant energy density functionals has been performed with the establishment of related theoretical uncertainties in the description of physical observables and their propagation towards the limits of nuclear existence. All even-even nuclei between the two-proton and two-neutron drip lines have been studied. Thus, the limits of nuclear landscape and theoretical uncertainties in its prediction have been defined. The sources of theoretical uncertainties in the prediction of the two-neutron drip line have been analyzed and it was concluded that they are dominated by single-particle degrees of freedom.

In addition to above mentioned extensive investigations we have performed a set of the studies which were focused on more narrow issues. First, we developed new and improved covariant energy density functional NL3* which is very frequently used nowadays. New class of rotational bands, namely, smooth terminating dipole bands, has been established and studied in detail on the example of the ^{110,112}Te nuclei. The additivity principle for physical observables and its violation have been studied in rotational structures of the $A \sim 130$ and $A \sim 70$ mass regions, respectively. Ultra high spin rotational bands in ^{158}Er have been investigated in covariant and non-relativistic density functional theories; according to theoretical interpretation these are highest spin bands ever observed. Smooth terminating, extended deformation and superdeformed rotational structures have been studied in the ^{107}In, ^{171,172,175}Hf and ^{154}Dy nuclei, respectively. In addition, the phenomenon of non-termination of collective rotation at I_{max} has been studied in ^{75}Rb. The gateway to superheavy nuclei has been probed via the study of single-particle spectra in odd-mass light superheavy nuclei (^{253}No, ^{255}Lr). Finally, the γ-softness of neutron-rich Mo and Ru nuclei has been investigated in detail.

All these results have contributed substantially to a better understanding of the proton-neutron pairing, the rotation, pycnonuclear reactions in the crust of neutron stars and interior of white dwarfs, the role of time-odd mean fields, the hyperdeformation, the fission, single-particle degrees of freedom and their interplay with collective vibrations, the limits of nuclear existence and theoretical uncertainties in the description of different physical observables.

2 Accomplishments

During the grant, the results of below discussed investigations were published.

2.1 Smooth terminating dipole bands

Our studies have established new type of terminating bands, namely, smooth terminating dipole bands [1,2]. Such structures were observed in the ^{110,112}Te nuclei and they were interpreted by us in terms of deformed structures built on proton 1-particle-1-hole excitations that reach band termination at $I \sim 40\hbar$ in a smooth way. Lifetime measurements have allowed the extraction of experimental $B(M1; I \rightarrow I-1)$ and $B(E2; I \rightarrow I-2)$ reduced transition rates. The M1 transition strength remains large in an extended spin range. This is contrary to the so-called magnetic (shears) bands, representing magnetic rotation, which loose their transition strength with increasing spin.

2.2 Proton-neutron pairing in rotating nuclei

Rotating $N \approx Z$ nuclei in the mass $A \sim 70$ mass region have been studied within the framework of the isovector mean field theory employing cranked relativistic mean field and cranked relativistic Hartree-Bogoliubov approaches with the goal to understand the role of isovector and isoscalar channels of neutron-proton pairing [3-6]. The systematic analysis of the rotational response and deformation properties supports the interpretation of these nuclei within the isovector mean field theory according to which only strong isovector pair field exists, which includes a large np component, the strength of which is determined by isospin conservation. Indeed, no clear evidence for the existence of the isoscalar $t = 0$ np pairing has been found.

2.3 The additivity principle in the density functional theory: test in the $A \sim 130$ mass region

The additivity principle of the extreme shell model stipulates that an average value of a one-body operator be equal to the sum of the core contribution and effective contributions of valence (particle or hole) nucleons. For quadrupole moment and angular momentum operators, we tested this principle for highly and superdeformed rotational bands in the $A \sim 130$ nuclei [7]. The calculations were done in the self-consistent cranked non-relativistic Hartree-Fock and relativistic Hartree mean-field approaches. Results indicate that the additivity principle is a valid concept that justifies the use of an extreme single-particle model in an unpaired regime typical of high angular momenta. They also indicate an important difference in the treatment of time-odd mean fields in non-relativistic and relativistic mean field models: the angular momenta are more additive in the relativistic framework.

2.4 Generalized theoretical approach for calculating pycnonuclear reaction rates

Generalized theoretical approach for calculating pycnonuclear reaction rates has been presented in [8]. This process is of interest for investigating thermal heating and nucleosynthesis near nuclear matter density conditions as anticipated in the interior of white dwarfs and in the crust of neutron stars. In particular, this study focuses on the theoretical description and analysis of the astrophysical S-factor at low energies. We compare S-factor predictions based on independent theoretical models such as coupled-channels and fermionic molecular dynamics models to investigate the reliability of a simple phenomenological barrier penetration model (San Paulo model) to derive pycnonuclear fusion rates between near and far of stability isotopes.

2.5 Large deformation rotational structures in the Hf isotopes

Prior to our investigation, it was thought that the strongly deformed bands observed in Hf isotopes represent triaxial superdeformed bands. However, no wobbling motion, a unique signature of nuclei with stable triaxiality, has been observed in these nuclei. This is contrary to the observation of wobbling motion in neighbouring Lu nuclei for which the existence of triaxiality is well established. Our theoretical investigation within the framework of the cranked relativistic mean field theory based on recent experimental data has resolved this obvious inconsistency [9]. According to our study, the bands in Hf isotopes represent near-prolate enhanced deformation bands or near-prolate superdeformed bands. Thus, no wobbling motion is expected in these bands.

2.6 Time-odd mean fields in terminating states

The analysis of the band termination process has been performed in the relativistic mean field framework [10]. It was shown that nuclear magnetism (time-odd mean fields) provide an additional binding to the energies of the specific configuration, and this additional binding increases with spin and has its maximum exactly at the terminating state. This suggests that the terminating states can be an interesting probe of time-odd mean fields provided that other effects can be reliably isolated. Unfortunately, a reliable isolation of these effects is not that simple: many terms of the density functional theories contribute to the energies of the terminating states, and the deficiencies in the description of those terms affect the result. The recent suggestion that the relative energies of the terminating states in the $N \approx Z$, $A \sim 44$ mass region provide unique and reliable constraints on time-odd mean fields and the strength of spin-orbit interaction in density functional theories has been reanalyzed. Our study shows that the relative energies of terminating states are affected also by the relative placement of the states with different orbital angular momentum l, namely, the placement of the $d(l = 2)$ and $f(l = 3)$ states, which depend on the properties of the central potential. As a result, it is difficult to use them to probe time-odd mean fields in a unique way.

2.7 Hyperdeformation at high spin

For the first time, the hyperdeformation (HD) at high spin has been studied in a systematic way within the framework of a fully self-consistent theory [11,12]. Cranking relativistic mean field theory is employed in this study which covers nuclei in the $Z = 40 - 58$ part of nuclear chart. The spins, at which the HD configurations become yrast, have been defined: in general, these configurations become yrast at lower spins in neutron-deficient nuclei than in the ones of the valley of β-stability. The density of the HD rotational bands is high in the spin range where they are yrast or close to yrast in the majority of cases. This feature will most likely prevent the observation of discrete HD bands because the feeding intensity will be redistributed among many bands, thus, dropping below the observational limit of experimental facilities. On the other hand, it will favor the observation of rotational patterns in the form of ridge structures in three-dimensional rotational mapped spectra: this represents another way of study of HD. It was found that the ^{96}Cd nucleus is a doubly magic HD nucleus due to large proton $Z = 48$ and neutron $N = 48$ HD shell gaps [12]. The best candidate for experimental search of discrete HD bands is ^{107}Cd nucleus [12] characterized by the large energy gap between the yrast and excited HD bands, the size of which is only 15% smaller than the one in doubly magic HD ^{96}Cd nucleus. The ^{108,109}Cd nuclei are alternative candidates.

Our self-consistent calculations suggest that necking degree of freedom should play an important role in some nuclei at hyperdeformation. With a very few exceptions, the HD shapes undergo a centrifugal stretching that results in an increase of the values of the transition quadrupole Q_t and mass hexadecapole Q_{40} moments as well as the dynamic moments of inertia $J^{(2)}$ with increasing rotational frequency. The variations in the kinematic moments of inertia $J^{(1)}$ with rotational frequency are rather small. These are the general features of the HD bands in unpaired regime which distinguish them from normal- and superdeformed bands [11]. Our study also shows that the individual properties of the single-particle orbitals are not lost at HD. They form the basis of the methods of the configuration assignment which employ the relative properties of different bands.

2.8 Violation of the additivity principle for physical observables in the $A \sim 70$ mass region.

Experimental data on relative transition quadrupole moments of rotational bands in ^{73,74}Kr and ^{74}Rb [13] as well as new data on deformation properties of the low-spin states in ^{74}Kr [6] have been analyzed in the relativistic framework. This has been done in order to understand whether the additivity principle for quadrupole moments and angular momenta is fulfilled in the nuclei characterized by a considerable softness in γ-deformation. The analysis of medium and high-spin data indicates that the additivity principle for these physical observables is violated. This is contrary to earlier confirmation of the additivity principle in the superdeformed bands of the $A \sim 130$ and $A \sim 150$ mass regions and the predictions from relativistic (cranked relativistic mean field theory) and non-relativistic (cranked Nilsson-Strutinsky) calculations. The reasons for the violation of additivity principle are not well understood, but the correlations beyond mean field are major suspect.

2.9 Improved parametrization of the relativistic mean field Lagrangian

Covariant density functional theory based on the relativistic mean field Lagrangian with the parameter set NL3 has been used during previous decade with great success. We derived a modification (called as NL3*) of this parameter set [14], which improves the description of the ground state properties of many nuclei and cures some problems observed previously with the NL3 force. At the same time, new parametrization provides an excellent description of excited states with collective character (rotational bands, giant resonances etc) in spherical as well as in deformed nuclei. This functional became quite popular in recent years.

2.10 Probing the gateway to superheavy nuclei

The heaviest actinide elements for which detailed spectroscopic data is available act as a gateway for the selection of different parametrizations of different models [15]. For example, the analysis of quasiparticle spectra in heaviest $A \sim 250$ nuclei strongly suggests that within the relativistic mean field theory only the parametrizations which predict $Z = 120$ and $N = 172$ as shell closures are reliable for superheavy nuclei [15]. Thus, the study of single-particle degrees of freedom in these nuclei is an important tool for better understanding and predictions of properties of superheavy elements. The cranked relativistic Hartree-Bogoliubov theory has been used in the interpretation of rotational structures and configuration assignment in ^{253}No [16] and ^{255}Lr [17]. Based on improved statistics the $\nu 9/2[734]$ configuration has been assigned to observed experimental band in ^{253}No [16]: its kinematic and dynamic moments of inertia are well reproduced in the CRHB calculations under such configuration assignment. The situation is less certain in the case of ^{255}Lr, the heaviest odd-Z nucleus for which detailed spectroscopic data is now available [17]. The analysis based on the single-particle energies obtained in the macroscopic+microscopic method favors the $\pi[624]9/2$ assignment for the bandhead of observed rotational band, while the analysis of rotational properties within the CRHB theory favors the $\pi 7/2[633]$ assignment [17]. Both these facts clearly indicate (i) the difficulties in the configuration assignments for heaviest odd-mass nuclei and (ii) the need for better and more systematic understanding of the accuracy of the description of moments of inertia (especially, in odd-mass nuclei) and the energies of single-particle states in the CRHB theory.

2.11 Excited superdeformed rotational bands in ^{154}Dy

Five new excited superdeformed bands (SD) have been observed in ^{154}Dy. The bands SD1, SD3, SD5, and SD6 were interpreted within the cranked relativistic mean field theory [18]. The high-N intruder configuration $\pi 6^4 \nu 7^2$ was suggested for SD1 band, and $\pi 6^4 \nu 7^3$ was suggested for SD3, SD5, and SD6 at frequencies above $\hbar\omega \sim 0.5$ MeV. The properties of these bands are well described in model calculations. The rise of dynamic moment of inertia $J^{(2)}$ moments with increasing rotational frequency, seen in bands SD2 and SD4, may indicate the presence of pairing and of band crossings. Those features cannot be addressed in the current calculations within the unpaired formalism.

2.12 Smooth terminating rotational bands in ^{107}In

The structure of nuclei close to ^{100}Sn has received increased attention in recent years. These studies have in particular highlighted the so-called *smooth band termination* phenomenon, following alignment of the valence nucleons outside the ^{100}Sn doubly magic core. A rotational band structure with ten E2 cascade transitions has been observed in ^{107}In using the JUROGAM detector array [19]. The kinematic ($J^{(1)}$) and dynamic ($J^{(2)}$) moments of inertia of observed band exhibit a gradual decrease with increasing rotational frequency, a typical characteristic of the smoothly terminating bands in this mass region. The experimental results were compared with Total Routhian Surface (TRS) and Cranked Nilsson-Strutinsky (CNS) calculations. According to the CNS calculations, the observed band is one transition short of termination [19].

2.13 Astrophysical S factors for fusion reactions involving C, O, Ne, and Mg isotopes

Using the Sao Paulo potential and the barrier penetration formalism we have calculated the astrophysical factor $S(E)$ for 946 fusion reactions involving stable and neutron-rich isotopes of C, O, Ne, and Mg for center-of-mass energies E varying from 2 to $\approx$ 1830 MeV (covering the range below and above the Coulomb barrier) [20,21]. We have parameterized the energy dependence, $S(E)$, by an accurate universal 9-parameter analytic expression and present tables of fit parameters for all the reactions. We also discuss the reduced 3-parameter version of our fit which is highly accurate at energies below the Coulomb barrier, and outline the procedure for calculating the reaction rates. The results can be easily converted to thermonuclear or pycnonuclear reaction rates to simulate various nuclear burning phenomena [21], in particular, stellar burning at high temperatures and nucleosynthesis in high density environments.

2.14 Time-odd mean fields in non-rotating systems in covariant density functional theory

Time-odd mean fields (nuclear magnetism) are analyzed in the framework of covariant density functional theory (CDFT) [22,23]. It is shown that they always provide additional binding to the binding energies of odd-mass nuclei. This additional binding only weakly depends on the RMF parametrization reflecting good localization of the properties of time-odd mean fields in CDFT. The underlying microscopic mechanism is discussed in detail. Time-odd mean fields affect odd-even mass differences. However, our analysis suggests that the modifications of the strength of pairing correlations required to compensate for their effects are modest. In contrast, time-odd mean fields have profound effect on the properties of odd-proton nuclei in the vicinity of proton-drip line. Their presence can modify the half-lives of proton-emitters (by many orders of magnitude in light nuclei) and affect considerably the possibilities of their experimental observation.

2.15 Impact of pairing on fission barriers

The impact of pairing correlations on the fission barriers is investigated in Relativistic Hartree Bogoliubov (RHB) theory and Relativistic Mean Field (RMF)+BCS calculations [24]. It it found that the pairing gap changes considerably with deformation and RMF+BCS calculations with constant gap do not provide an adequate description of the barriers. Monopole or zero range pairing forces depend at least on two parameters, the strength and the cutoff energy. They are usually adjusted to the experimental pairing properties in the ground state for a fixed value of the cutoff energy. It is shown that this procedure leaves room for uncertainties in the fission barrier heights [24,26] which can reach 0.5-1.0 MeV in some cases. The Gogny force in the pairing channel with its finite range does not show this deficiency, because it does not require an artificial cutoff in energy or in momentum. RHB calculations show that there is a substantial difference in the predicted barrier heights between zero-range and finite range pairing forces even in the case when the pairing strengths of these two forces are adjusted to the same value of the pairing gap at the ground state. For zero range forces the barrier heights depend on the renormalization procedure.

2.16 Time-odd mean fields in rotating systems in covariant density functional theory

Time-odd mean fields (nuclear magnetism) and their impact on physical observables in rotating nuclei are studied in the CDFT framework [25]. It is shown that they have profound effect on the dynamic and kinematic moments of inertia. Particle number, configuration and rotational frequency dependences of their impact on the moments of inertia have been analysed in a systematic way. Nuclear magnetism can also considerably modify the band crossing features such as crossing frequencies and the properties of the kinematic and dynamic moments of inertia in the band crossing region. The impact of time-odd mean fields on the moments of inertia in the regions away from band crossing only weakly depends on the relativistic mean field parametrization, reflecting good localization of the properties of time-odd mean fields in CDFT. The moments of inertia of normal-deformed nuclei considerably deviate from the rigid body value. On the contrary, superdeformed and hyperdeformed nuclei have the moments of inertia which are close to rigid body value. The structure of the currents in rotating frame, their microscopic origin and the relations to the moments of inertia have been systematically analysed. The phenomenon of signature separation, induced by time-odd mean fields, has been analysed in detail with the focus on two-particle configurations of odd-odd nuclei.

2.17 Triaxiality of fission barriers in the actinides

The first systematic investigation of triaxial fission barriers in the actinide region has been performed within CDFT in Refs. [26,30,33]. The calculations have been carried out with the parameter set NL3* and they have been compared in specific cases also with the results of parameter sets DD-ME2 and DD-PC1. Pairing correlations are taken into account in the BCS approximation using seniority zero forces adjusted to empirical values of the gap parameters. It is found that with only one exception (^{234}Th) in all the nuclei under investigation the height of the inner fission barrier is reduced by allowing for triaxial deformations by $1-3$ MeV. The fission path avoids a maximum of the axially symmetric potential energy surface between the first and the second minimum by going through a valley in the (β, γ) plane with a triaxial deformation $\gamma \approx 10°$. A systematic comparison of our results with experimentally determined fission barriers in this region shows very good agreement with data (average deviation from experiment per barrier is only 0.76 MeV) which is comparable with the best macroscopic+microscopic calculations [26,33].

2.18 Non-termination of collective rotation at I_{max}

At present, detailed understanding of the process of band termination has been achieved both experimentally and theoretically. However, not all rotational bands are expected to terminate in a non-collective state at I_{max}, but experimental data for the phenomenon of non-termination of rotational bands at I_{max} was available so far only in ^{74}Kr. We report evidence for the second example of the observation of non-termination of rotational bands at I_{max} in ^{75}Rb which is supported by the mean field calculations [27]. Two of the four known rotational bands in ^{75}Rb have been studied up to and one transition short of the maximum spin I_{max} of the assigned configurations. Cranked Nilsson-Strutinsky calculations indicate that these rotational bands do not terminate at I_{max}. This result is supported by the cranked relativistic mean field calculations. The residual Doppler shift attenuation method has been used to measure the lifetimes of the states in these two bands and transition quadrupole moments have been extracted. In agreement with the calculations transition quadrupole moments show a small decrease with spin and remain large at the highest spins, suggesting that the bands remain collective up to their maximum spins I_{max}.

2.19 Dynamics of nuclear single-particle structure in covariant theory of particle-vibration coupling

The impact of particle-vibration coupling and polarization effects due to deformation and time-odd mean fields on single-particle spectra is studied systematically in doubly magic spherical nuclei from low mass ^{56}Ni up to superheavy ones in [28,29,30]. Particle-vibration coupling is treated fully self-consistently within the framework of relativistic particle-vibration coupling model. Polarization effects due to deformation and time-odd mean field induced by odd particle are computed within covariant density functional theory. It has been found that among these contributions the coupling to vibrations makes a major impact on the single-particle structure. The impact of particle-vibration coupling and polarization effects on calculated single-particle spectra, the size of the shell gaps, the spin-orbit splittings and the energy splittings in pseudospin doublets is discussed in detail; these physical observables are compared with experiment. Particle-vibration coupling has to be taken into account when model calculations are compared with experiment since this coupling is responsible for observed fragmentation of experimental levels; experimental spectroscopic factors are reasonably well described in model calculations.

2.20 Deformed one-quasiparticle states in covariant density functional theory

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 density functional theory framework [31]. This analysis covers actinide and rare-earth mass regions. 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. While the solution of the latter problem can be attempted in the framework of density functional theory, we do not believe that it will lead to significant improvements in spectroscopic quality of energy density functionals. The comprehensive solution requires taking into account particle-vibration coupling which will compress the calculated one-quasiparticle spectra bringing them closer to experiment [31] and correct the relative energies of different single-particle states. The analysis suggests that only such approach combined with respective re-parametrization of the covariant density functional Lagrangian can lead to spectroscopic quality energy density functionals. It should be noted, however, that the errors in the description of the energies of deformed single-particle states have very small impact on polarization and/or alignment effects induced by a particle [31] and collective features such as fission barrier heights [33].

2.21 Fission barriers in superheavy nuclei

We have carried out systematic investigations of fission barriers in even-even superheavy nuclei with $Z = 112 - 120$ within covariant density functional theory including triaxial shapes with D2 symmetry and octupole shapes with axial symmetry [32-36]. Three different classes of models with the state-of-the-art parametrizations NL3*, DD-ME2, and DD-PC1 were used in the calculations. Pairing correlations are taken into account in the BCS approximation using seniority pairing forces adjusted to empirical values of the gap parameters. The low-Z and low-N nuclei in this region are characterized by axially symmetric inner fission barriers. The increase of the particle numbers leads to a softening of the potential energy surfaces in the triaxial plane. As a result, several competing fission paths in the region of the inner fission barrier emerge in some of the nuclei. Triaxiality lowers the outer fission barriers by 1.5-3 MeV in reflection-symmetric calculations. In many nuclei the lowering due to triaxiality is even more important than the one due to octupole deformation. The underlying shell structure clearly defines a triaxial (octupole) saddle for second fission barrier that is lower in energy for proton-rich nuclei with $N < 174$ (neutron-rich nuclei with $N > 174$). The detailed comparison of the CDFT results with non-relativistic ones was presented in [32].

2.22 Pycnonuclear reactions in the crust of neutron stars

Nuclear burning is an important ingredient of stellar structure and evolution. In particular, pycnonuclear reactions play an important role in thermal heating and nucleosynthesis near nuclear matter densities anticipated in the interior of white dwarfs and in the crust of neutron stars. They also affect the composition of the crust of neutron stars as a function of depth (density). Self-consistent network calculations aimed on the calculations of the composition of the crust require extensive databases of the pycnonuclear reaction rates between all possible reactants. We have created a large database of astrophysical $S(E)$-factors for non-resonant pycnonuclear reactions as a function of center-of-mass energy E of colliding nuclei (below and above the Coulomb barrier). Using the Sao Paulo potential and the barrier penetration formalism with nuclear densities obtained in the relativistic Hartree-Bogoliubov approach, we have calculated about 5,000 $S-$factors [37,38]. The current database includes about 5,000 reactions involving stable and unstable isotopes of Be, B, C, N, O, F, Ne, Na, Mg, and Si located between proton- and neutron-drip lines. The energy dependence $S(E)$ has been parametrized by an improved and accurate analytic expression. For a given reaction, the present $S(E)$-model contains three parameters. These parameters are easily interpolated along reactions involving isotopes of the same elements with only seven input parameters. In this way we obtain an ultracompact, accurate, simple, and uniform database [37]. We have analyzed the range of variations of $S(E)$ due to in-medium modifications of interaction potential $U(r)$ for the pycnonuclear ^{34}Ne+^{34}Ne reaction in the inner crust of an accreting neutron star (with the conclusion that the variations can reach several orders of magnitude).

2.23 Ultra-high spin rotational bands of ^{158}Er in nuclear density functional theory.

Rotational bands in ^{158}Er at ultrahigh spin have been studied in the framework of relativistic and nonrelativistic nuclear density functional theories [39]. Consistent results are obtained across the theoretical models used but some puzzles remain when confronted with experiment. Namely, the many-body configurations which provide good description of experimental transition quadrupole moments and dynamic moments of inertia require substantial increase of the spins of observed bands as compared with experimental estimates, which are still subject to large uncertainties. If, however, the theoretical spin assignments turned out to be correct, experimental band 1 in ^{158}Er would be the highest spin structure ever observed.

2.24 Isoscalar and isovector neutron-proton pairing

The physics of isoscalar and isovector neutron-proton pairing has been systematically reviewed in [40]. At present, the existence of isovector np-pairing is well established. The isovector $np-$pairing is absolutely necessary in order to restore the isospin symmetry of the total wave function. Its strength is well defined by the isospin symmetry. A number of experimental observables such as binding energies of the $T = 0$ and $T = 1$ states in even-even and odd-odd $N = Z$ nuclei, the structure of rotational bands in ^{74}Rb and pairing vibrations around ^{56}Ni strongly support its existence.

On the contrary, the observed consequences of the $t = 0$ $np-$pairing still remain illusive. The existence of the pair condensate in this channel sensitively depends on employed pairing strength. However, microscopic theories give no guidance on what strength has to be used for isoscalar $np-$pairing in the mean-field/density functional theoretical models. The use of experimental Wigner energies as a tool to extract this strength faces the dilemma that these energies are not necessary due to isoscalar $np-$pairing. Other observables in non-rotating nuclei either do not support the existence of this type of pairing or insensitive to it. The systematic analysis of rotational response of $N \approx Z$ nuclei agrees with the picture which does not involve isoscalar $np-$pairing. According to it (isovector mean-field theory), at low spin, an isoscalar $np-$pair field is absent while a strong isovector pair field exists, which includes a large np component, whose strength is determined by isospin conservation. Like in nuclei away from the $N = Z$ line, this isovector pair field is destroyed by rotation. In this high-spin regime, calculations without pairing describe accurately the data, provided that the shape changes and band termination are taken into account. Although the current analysis does not support the existence of isoscalar $np-$pairing, the possibility of its existence cannot be completely ruled out due to the limitations of existing theoretical tools.

2.25 Testing γ-softness in neutron-rich Mo and Ru nuclei

The transition quadrupole moments, Q_t, of rotational bands in the neutron-rich, even-mass $^{102-108}$Mo and $^{108-112}$Ru nuclei were measured in the $8-16\hbar$ spin range with the Doppler-shift attenuation method [41]. The nuclei were populated as fission fragments from ^{252}Cf fission. The detector setup consisted of the Gammasphere spectrometer and the HERCULES fast-plastic array. At moderate spin, the Q_t moments are found to be reduced with respect to the values near the ground states. Attempts to describe the observations in mean-field-based models, specifically cranked relativistic Hartree-Bogoliubov theory, illustrate the challenge theory faces and the difficulty to infer information on γ-softness and triaxiality from the data [41].

2.26 Pairing and rotational properties of actinides and superheavy nuclei in covariant density functional theory.

The cranked relativistic Hartree-Bogoliubov (CRHB) theory has been applied for a systematic study of pairing and rotational properties of actinides and light superheavy nuclei [42,43]. Pairing correlations are taken into account by the Brink-Booker part of finite range Gogny D1S force. For the first time in the covariant density functional theory (CDFT) framework the pairing properties are studied via the quantities (such as three-point $\Delta^{(3)}$ indicators) related to odd-even mass staggerings. The investigation of the moments of inertia at low spin and the $\Delta^{(3)}$ indicators shows the need for an attenuation of the strength of the Brink-Booker part of the Gogny D1S force in pairing channel. The investigation of rotational properties of even-even and odd-mass nuclei at normal deformation, performed in the density functional theory framework in such a systematic way for the first time, reveals that in the majority of the cases the experimental data are well described and the model possesses a good predictive power. These include the evolution of the moments of inertia with spin, band crossings in the $A \geq 242$ nuclei, the impact of the particle in specific orbital on the moments of inertia in odd-mass nuclei. The analysis of the discrepancies between theory and experiment in the band crossing region of $A \leq 240$ nuclei suggests the stabilization of octupole deformation at high spin, not included in the present calculations. The evolution of pairing with deformation, which is important for the fission barriers, has been investigated via the analysis of the moments of inertia in the superdeformed minimum. The dependence of the results on the CDFT parametrization has been studied by comparing the results of the calculations obtained with the NL1 and NL3* parametrizations.

2.27 The limits of nuclear landscape

The first ever systematic investigation of the location of the proton and neutron drip lines in the covariant density functional theory has been performed by employing a set of the state-of-the-art parametrizations [44]. Calculated theoretical uncertainties in the positions of two-proton and two-neutron drip lines are compared with those obtained in non-relativistic DFT calculations. These results clearly indicate that the shell structure is not washed near or at two-neutron drip line. In particular, model uncertainties in the definition of two-neutron drip line at $Z \sim 54, N = 126$ and $Z \sim 82, N = 184$ are very small due to the impact of spherical shell closures at $N = 126$ and 184. The largest difference between covariant and Skyrme DFT exist in superheavy nuclei, where the first model (contrary to second) predicts significant impact of the $N = 258$ spherical shell closure. The spread of theoretical predictions grows up on moving away from these spherical closures. The development of deformation causes it. Both poorly known isovector properties of the forces and inevitable inaccuracies in the description of deformed single-particle states in the DFT framework contribute to that. Our calculations support the estimate, obtained in non-relativistic framework, that around 7000 different (including odd- and odd-odd ones) nuclides have to exist.

2.28 Global performance of covariant energy density functionals: Ground state observables of even-even nuclei and the estimate of theoretical uncertainties

The current investigation (published in [45,46]) aims at the global assessment of the accuracy of the description of the ground state properties of even-even nuclei. We also estimate theoretical uncertainties defined here as the spreads of predictions within four covariant energy density functionals in known regions of the nuclear chart and their propagation towards the neutron drip line. Large-scale axial relativistic Hartree-Bogoliubov calculations are performed for all $Z \leq 104$ even-even nuclei between the two-proton and two-neutron drip lines with four modern covariant energy density functionals such as NL3*, DD-ME2, DD-MEδ, and DD-PC1. The physical observables of interest include the binding energies, two-particle separation energies, charge quadrupole deformations, isovector deformations, charge radii, neutron skin thicknesses, and the positions of the two-proton and two-neutron drip lines. The predictions for the two-neutron drip line are also compared in a systematic way with the ones obtained in nonrelativistic models.

2.29 Addressing spectroscopic quality of covariant density functional theory.

The spectroscopic quality of covariant density functional theory has been accessed in [48] by analyzing the accuracy and theoretical uncertainties in the description of spectroscopic observables. Such analysis is first presented for the energies of the single-particle states in spherical and deformed nuclei. It is also shown that the inclusion of particle-vibration coupling improves the description of the energies of predominantly single-particle states in medium and heavy-mass spherical nuclei. However, the remaining differences between theory and experiment clearly indicate missing physics and missing terms in covariant energy density functionals. The uncertainties in the predictions of the position of two-neutron drip line sensitively depend on the uncertainties in the prediction of the energies of the single-particle states. On the other hand, many spectroscopic observables in well deformed nuclei at ground state and finite spin only weakly depend on the choice of covariant energy density functional.

2.30 Neutron drip line: single-particle degrees of freedom and pairing properties as sources of theoretical uncertainties

The sources of theoretical uncertainties in the prediction of the two-neutron drip line are analyzed in the framework of covariant density functional theory in [49]. We concentrate on single-particle and pairing properties as potential sources of these uncertainties. The major source of these uncertainties can be traced back to the differences in the underlying single-particle structure of the various covariant energy density functionals (CEDF). It is found that the uncertainties in the description of single-particle energies at the two-neutron drip line are dominated by those existing already in known nuclei. Only approximately one third of these uncertainties are due to the uncertainties in the isovector channel of CEDF's. Thus, improving the CEDF description of single-particle energies in known nuclei will also reduce the uncertainties in the prediction of the position of two-neutron drip line. The predictions of pairing properties in neutron rich nuclei depend on the CEDF. Although pairing properties affect moderately the position of the two-neutron drip line they represent only a secondary source for the uncertainties in the definition of the position of the two-neutron drip line.

2.31 Nuclear structure theory of the heaviest nuclei

The current status of the application of covariant density functional theory to the description of actinides and superheavy nuclei is reviewed in Ref. [50]. The achievements and open problems are discussed. The uncertainties in the description of the energies of the single-particle states and the sizes of the shell gaps have been analyzed. Relatively small sizes of the shell gaps in the SHN imply that these uncertainties can have a profound effect on the reliability of the predictions. In such a situation other effects (such as softness of potential energy surface) have to be taken into account in analyzing the shell structure of SHN. The differences in the predictions of the fission barriers of superheavy nuclei in different theoretical frameworks have been discussed. Finally, the accuracy of the description of rotational properties of actinides and superheavy nuclei and the possibility of their use for configuration assignment in odd-mass light superheavy nuclei have been analyzed.

3 Publications

1. E. S. Paul, K. Starosta, A. O. Evans, A. J. Boston, H. J. Chantler, C. J. Chiara, M. Devlin, A. M. Fletcher, D. B. Fossan, D. R. LaFosse, G. J. Lane, I. Y. Lee, A. O. Macchiavelli,

P. J. Nolan, D. G. Sarantites, J. M. Sears, A. T. Semple, J. F. Smith, C. Vaman, **A. V. Afanasjev**, I. Ragnarsson,
Smooth terminating bands in ^{112}Te: particle-hole induced collectivity,
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Physical Review C 76 (2007) 064321: 1-10

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Neutron drip line: single-particle degrees of freedom and pairing properties as sources of theoretical uncertainties,
Physical Review C 91, 014324 (2015) 1-17

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Nuclear structure theory of the heaviest nuclei,
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4 Presentations

4.1 Presentations of Principal Investigator at the International Conferences/Workshops

1. Division of Nuclear Physics Town Meeting for NSAC Long Range Plan, January 19-21, 2007, Chicago, USA
Relativistic Mean Field Approaches
invited speaker

2. Mississippi Academy of Science 2007 annual meeting, February 22-23, 2007, Starkville, USA
Superheavy nuclei: a search for an island of stability
contributed talk

3. Gordon Research Conference on Nuclear Chemistry, Colby-Sawyer College, New Hampshire, USA, June 3 - 8, 2007
Superheavy nuclei: theoretical challenges
invited speaker

4. International Workshop on Nuclear Structure NS07: New Pictures in the extended Isospin Space, June 11-14, 2007, Yukawa Institute for Theoretical Physics, Kyoto University, Kyoto, Japan
Superheavy nuclei: self-consistency effects and single-particle degrees of freedom
invited talk

5. 2007 Annual Fall meeting of the Division of Nuclear Physics, American Physical Society, October 11, 2007, Newport News, Virginia, USA
Band Termination and Density Functional Theory
contributed talk [12 min]

6. 2007 Annual Fall meeting of the Division of Nuclear Physics, American Physical Society, October 13, 2007, Newport News, Virginia, USA
Hyperdeformation in the cranked relativistic mean field theory
contributed talk [12 min]

7. Fourth International Conference on "Fission and Properties of Neutron-Rich nuclei", November 14, 2007, Sanibel Island, Florida, USA
Relativistic mean field studies of superheavy nuclei

8. DFT-UNEDF workshop "Determination of the Nuclear Energy Functional: Optimization Strategy, Essential Experimental Data and Chi-Squared Mertrics", Joint Institute for Heavy Ion Research, Oak Ridge National Laboratory, January 22, 2008, Oak Ridge, USA,
Terminating states: Can they be used to constraint DFT?

contributed talk [10 min]

9. The 2d LACM-EFES-JUSTIPEN Workshop, Joint Institute for Heavy Ion Research, Oak Ridge National Laboratory, January 23-25, 2008, Oak Ridge, USA.
Hyperdeformation: a microscopic outlook
invited talk [20 min]

10. International conference "Nuclear Structure'08", June 3-6, 2008, East Lansing, Michigan, USA
Hyperdeformation in the cranked relativistic mean field theory: questions and answers
contributed talk [20 min]

11. The 2-nd International Conference "Current Problems in Nuclear Physics and Atomic Energy", June 9-15, 2008, Kiev, Ukraine
Superheavy and rotating nuclei within the framework of relativistic Hartree-Bogoliubov theory
invited talk [30 min]

12. International workshop on "Scaling the heights of the N=Z line above 56-Ni", European Centre for Theoretical Studies in Nuclear Physics and Related Areas, Trento, Italy, September 16-19, 2008
Neutron-proton pairing and other "new" physics in rotating $N \sim Z$ nuclei
keynote speaker [45 min]

13. International conference "Nuclear Structure and Dynamics", Dubrovnik, Croatia, May 4-8, 2009
Covariant Density Functionals: time-odd channel investigated.
contributed talk [20 min]

14. Institute for Nuclear Theory workshop "Effective Field Theories and the Many-Body Problem", March 23 - June 5, 2009, Seattle, USA
Understanding time-odd mean fields in covariant density functional theories
oral presentation [75 min]

15. International conference "Nuclear Structure and Related Topics", Dubna, Russia, June 30 - July 4, 2009
Time-odd mean fields in density functional theories,
invited talk [20 min]

16. Mississippi State University, Research Showcase, College of Arts and Sciences, October 22, 2009
Superheavy nuclei: A journey to the island of stability
conference-type presentation [20 min]

17. JUSTIPEN-EFES workshop on unstable nuclei, RIKEN, Japan, December 7-9, 2009
Covariant density functional studies of time-odd mean fields and fission barriers
oral presentation [30 min]

18. The VI International workshop on direct reactions with exotic beams, Florida State University, Tallahassee, FL, USA, December 16-19, 2009,
The fission barriers in covariant density functional theory: superheavy nuclei and the role of pairing.
oral presentation [20 min]

19. The 4th LACM-EFES-JUSTIPEN Workshop, Joint Institute for Heavy Ion Research, Oak Ridge, Tennessee, USA, Oak Ridge National Laboratory March 15-17, 2010
Fission Barriers in Covariant Density Functional theory
oral presentation [30 min]
JUSTIPEN = Japan-US Theory Institute for Physics with Exotic Nuclei
LACM= nuclear large amplitude collective motion
EFES = JSPS Core-to-Core program "International Research Network for Exotic Femto Systems (EFES)"

20. The second international EURORIB (European Radioactive Ion Beam) conference "EURORIB'10", 06/06/10 - 06/11/10, Lamoura, France.
Heavy and superheavy nuclei in the covariant density functional theory,
oral presentation [20 min]

21. 2010 International Nuclear Physics Conference (INPC 2010), 07/04-07/09/2010, Vancouver, Canada
Spectroscopy of the heaviest elements (Theory)
invited talk at parallel session [25 min]

22. GRETINA Science Collaboration Meeting, 10/14-10/15/2010, Argonne National Laboratory, Physics Division, USA
Superheavy nuclei: theoretical perspectives and suggestions for experiments
invited talk [45 min]

23. University of Aizu-JUSTIPEN-EFES symposium "Cutting-Edge Physics of Unstable Nuclei", 10/10-10/13/2010, Aizu-Wakamatsu, Japan,
Fission barriers in actinides and superheavy nuclei: CDFT perspective.
oral presentation [25 min].

24. Third workshop "Nuclei and Mesoscopic physics", Michigan State University, East Lansing, Michigan, USA, 03/09/2011
Pairing in nuclear systems: open questions
invited talk [60 min]

25. The 5th LACM-EFES-JUSTIPEN Workshop, Joint Institute for Heavy Ion Research,

Oak Ridge, Tennessee, USA, Oak Ridge National Laboratory, March 15-17, 2011
Single-particle states in covariant DFT: at and beyond mean field level
oral presentation [30 min]

26. International symposium "Advances in Nuclear Many-Body Theory", Primosten, Croatia, June 7-10, 2011
Single-particle degrees of freedom in covariant density functional theory
invited talk [30 min]

27. Joint ATLAS-HRIBF-NSCL-FRIB User Workshop, National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, MI, USA, August 18-20, 2011
Superheavy nuclei: theoretical perspective
invited talk [25 min] at parallel breakout session "Superheavy elements"

28. YIPQS Long-term workshop "Dynamics and correlations in exotic nuclei (DCEN2011)", Yukawa Institute for Theoretical Physics, Kyoto, Japan, September 20 - October 28, 2011
Spectroscopic quality energy density functionals: problems and solutions.
oral presentation [40 min] given on September 23.

29. YIPQS Long-term workshop "Dynamics and correlations in exotic nuclei (DCEN2011)", Yukawa Institute for Theoretical Physics, Kyoto, Japan, September 20 - October 28, 2011
Fission barriers: open problems.
oral presentation [30 min] given on September 21 in the discussion session on fission barriers.

30. 18^{th} Nuclear Physics Workshop "Marie & Pierre Curie", Kazimierz, Poland, September 28 - October 2, 2011
Recent progress in the study of fission barriers in covariant density functional theory
invited talk [45 minutes]

31. Collaboration Meeting, CAE, Saclay, France, April 10-11, 2012
Single-particle degrees of freedom within the covariant EDF method
oral presentation [60 min]

32. FUSTIPEN topical meeting "The structure of heavy nuclei", GANIL, Caen, France, April 16-17, 2012,
The structure of heavy nuclei in DFT: from actinides to superheavies
invited talk [80 min]

33. FUSHE 2012 - ENSAR-ECOS workshop on FUture SuperHeavy Element Strategy, Erbismuhle - Weilrod, Germany, May 13-16, 2012,
Theory: Ground state properties and the limits of the region of superheavy elements
invited talk [50 min]

34. International conference “Nuclear Structure 2012”, Argonne National Laboratory, Lemont, IL, USA, August 13-17, 2012,
Towards spectroscopic quaility energy density functionals
oral presentation [20 min]

35. Low Energy Community Meeting, Argonne National Laboratory, Lemont, IL, USA, August 17-18, 2012
Theory of superheavy elements: current status and challenges.
invited talk [20 min] at working group meeting “Superheavy Elements”

36. The 6th LACM-TORIJIN-JUSTIPEN Workshop,Joint Institute for Heavy Ion Research, Oak Ridge, Tennessee, Oak Ridge National Laboratory, Oak Ridge, TN, USA, October 31 - November 2, 2012
Actinides and superheavy elements: pairing, single-particle and rotational properties revisited.
oral presentation [30 min]

37. Fifth international conference on **Fission and Properties of Neutron-Rich Nuclei**, November 4-10, 2012, Sanibel Island, Florida, USA,
Fission of actinides and superheavy nuclei: covariant density functional theory perspective.
invited talk [25 min]

38. Fifth International Workshop on Nuclear fission and Fission-Product Spectroscopy, May 28-31, 2013, Caen, France,
Nuclear fission in covariant density functional theory.
contributed talk [20 min]

39. Department of Energy Comparative Review of Nuclear Theory, Gaithersburg, MD, 22 June, 2013,
Nuclear at extreme conditions: a relativistic study
talk [30 min]

40. 20^{th} Nuclear Physics Workshop “Marie & Pierre Curie”, September 25-29, 2013, Kaziemierz, Poland,
Microscopic description of rotation: from ground states to the extremes of ultra-high spin
invited talk [30 min]

41. Institute for Nuclear Theory Program INT-13-3 “Quantitative Large Amplitude Shape Dynamics: fission and heavy ion fusion”, September 23 - November 15, 2013 (presentation on October 1, 2013)
Fission in covariant DFT: status and open questions
invited talk [60 min]

42. JUSTIPEN-JUSEIPEN Workshop, December 9-12, 2013, RIKEN Wako campus, Japan
Global performance of covariant energy density functionals: from proton to neutron drip lines
contributed talk [25 min]

43. The 2^d CUSTIPEN Workshop on "Advances in the computational nuclear many-body problems", December 15-17, 2013, Beijing, Peking University, China
Nuclear landscape in covariant density functional theory,
talk [40 min]

44. American Physical Society meeting, April 5-8, 2014, Savannah, Georgia, USA
Reflection asymmetric shapes in covariant density functional theory.
contributed talk [12 min]

45. Fourth workshop "Nuclei and Mesoscopic Physics 2014", Michigan State University, National Superconducting Cyclotron Laboratory, East Lansing, Michigan, USA, May 5-9, 2014
Nuclear energy density functionals: what we can learn about/from their global performance
oral talk [40 min]

46. EBBS2014: Exotic Beam Summer School 2014 at Oak Ridge National Laboratory, July 28 - August 1, 2014
Nuclear structure
invited lecture course [50 + 50 min]

47. Zakopane Conference on Nuclear Physics "Extremes of the Nuclear Landscape", Zakopane, Poland, August 31 - September 7, 2014
Nuclear structure theory of the heaviest nuclei
invited talk [30 min]

48. 4th Joint Meeting of the Nuclear Physics Divisions of the American Physical Society and the Physical Society of Japan, Workshop "Physics Opportunities with High-resolution Spetrometers CAGRA and GRAND RAIDEN", October 7-11, 2014, Hilton Waikoloa Village, Big Island, Hawaii.
Superdeformation and hyperdeformation in the $A \sim 40$ mass region
invited talk [30 min]

49. 4th Joint Meeting of the Nuclear Physics Divisions of the American Physical Society and the Physical Society of Japan, October 7-11, 2014, Hilton Waikoloa Village, Big Island, Hawaii
The competition of particle-vibration coupling and tensor interaction in spherical nuclei
talk [15 min]

50. SERC School on Modern Theories of Nuclear Structure, Department of Physics, Indian Institute of Technology Roorkee, Roorkee - 247667, February 23 - March 3, 2015, India
Nuclear structure in covariant density functional theory
invited course of lectures, consisted of six 75 minutes lectures and one computer session. The titles of the lectures are:
A. **Nuclear structure (part 1): covariant density functional theory - a basis**
B. **Nuclear structure (part 2): testing a nuclear landscape from known to neutron-rich and superheavy nuclei**
C. **Nuclear structure (part 3): single-particle degrees of freedom - at and beyond mena field level**
D. **Nuclear structure (part 4): rotation - from ground states to the extremes of high spin and deformation**
E. **Nuclear structure (part 5): microscopic theory of fission**

4.2 Colloquia and Seminars presented by Principal Investigator

1. Florida State University, March 15, 2007
Physics in the vicinity of the $N = Z$ line: a current status.
invited seminar [60 min]

2. Physics Division, Argonne National Laboratory, Argonne, Illinois, USA, 09/24/2007
Band Termination revisited
invited seminar [60 min]

3. Lawrence Berkeley National Laboratory, Nuclear Science Division, Berkeley, California, USA, 02/07/2008
Nuclear extremes in the relativistic mean field theory: hyperdeformation and superheavy nuclei. Part 1: Hyperdeformation in the $Z = 40 - 58$ part of nuclear chart
invited seminar [60 min]

4. Lawrence Berkeley National Laboratory, Nuclear Science Division, Berkeley, California, USA, 02/08/2008
Nuclear extremes in the relativistic mean field theory: hyperdeformation and superheavy nuclei. Part 2: Superheavy nuclei
seminar [60 min]

5. RIKEN Nishina Center for Accelerator-Based Science, Japan, 05/12/2008
The next frontier: hyperdeformation
seminar [60 min]

6. RIKEN Nishina Center for Accelerator-Based Science, Theory group seminar, Japan, 05/16/2008
Few words about time-odd mean fields
seminar [80 min]

7. Yukawa Institute of Theoretical Physics, Kyoto University, Japan, 05/23/2008.
Time-odd mean fields in density functional theories
seminar [60 min]

8. Division of Mathematical Physics, Lund Institute of Technology, Lund, Sweden, 06/18/2008
Hyperdeformation: a microscopic study
seminar [60 min]

9. Physik-Department der Technischen Universität München, Garching, Germany, 08/10/2008
The next frontier - hyperdeformation: A study within the covariant density functional theory
colloqium [60 min]

10. Institute of Solid State Physics, University of Latvia, Latvia, 06/16/2008
Recent progress in the study of rotating nuclei within the relativistic framework
seminar [60 min]

11. Department of Physics, University of Padova, Italy, 09/15/2008
Challenges in high-spin physics: theoretical perspective
seminar [60 min]

12. Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA, 03/19/2009
Probing nuclear extremes with covariant density functional theory
invited seminar [60 min]

13. Department of Physics and Astronomy, University of Thessaloniki, Greece, 06/19/2009
Recent progress in covariant density functional theory
invited seminar [60 min]

14. Flerov's Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Dubna, Russia, 06/29/2009
Superheavy nuclei in covariant density functional theory
invited all-lab scientific seminar [70 min]

15. Institute of Solid State Physics, University of Latvia, Latvia, 07/07/2009
Covariant density functional theory: nuclear magnetism and its role
invited seminar [60 min]

16. Department of Physics, University of Alabama, Tuscalloosa, USA, 01/13/2010.
Covariant density functional theory: the framework and applications to nuclear structure and nuclear astrophysics.
invited colloqium [50 min]

17. Physics Division, Argonne National Laboratory, Argonne, Illinois, USA, 04/26/2010

Recent advances in covariant density functional theory
invited seminar [60 min]

18. Division of Mathematical Physics, Lund Institute of Technology, Lund, Sweden, 05/19/2010
The physics of time-odd mean fields
invited seminar [70 min]

19. Physik-Department der Technischen Universität München, Garching, Germany, 05/27/2010
Understanding superheavies through the prizm of heavies.
invited colloqium [60 min]

20. Institute of Solid State Physics, University of Latvia, Latvia, 06/04/2010
Nuclear burning in neutron star crust
invited seminar [70 min]

21. Department of Physics, University of Tennessee, Knoxville, USA, 10/18/2010
Time-odd mean fields in non-rotating and rotating nuclei
invited seminar [60 min]

22. Institute of Solid State Physics, University of Latvia, Latvia, 06/13/2011
Nuclear energy density functionals: from collective to single-particle degrees of freedom.
invited seminar [60 min]

23. Mississippi State University, Starkville, USA, 11/31/2011
Neutron stars: nuclear burning in the crust.
colloqium [60 min]

24. Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA, 03/15/2012
Heavy and superheavy nuclei in relativistic framework.
invited seminar [65 min]

25. Lawrence Berkeley National Laboratory, Nuclear Science Division, Berkeley, California, USA, 03/19/2012
Recent progress in covariant density functional theory.
seminar [60 min]

26. Department of Physics, University of Tennessee, Knoxville, USA, 04/23/2012
Single-particle degrees of freedom in covariant density functional theory
invited seminar [60 min]

27. Division of Mathematical Physics, Lund Institute of Technology, University of Lund, Lund, Sweden, 05/21/2012,
Nuclear density functional theory: single-particle motion
invited seminar [70 min]

28. Institute of Solid State Physics, University of Latvia, Latvia, 05/30/2012
Superheavy elements: current status and future.
invited colloqium [70 min]

29. Department of Physics, University of Padova, Italy, 06/07/2012
Covariant density functional theory: heavy and superheavy nuclei.
invited seminar [55 min]

30. Institut de Recherches Subatomiques, Unite mixte de Recherche CNRS-IN2P3 et Universite Louis Pasteur, Strasbourg, France, 06/12/2012
Recent progress in covariant DFT: time-odd mean fields and single-particle degrees of freedom
invited seminar [60 min]

31. Mississippi State University, Department of Physics, Starkville, USA, 10/25/2012
Theoretical/computational low-energy nuclear physics: personal perspective [current status and future]
invited seminar [55 min]

32. Washington University in St. Louis, Department of Chemistry, Saint Louis, USA, 11/16/2012
Covariant density functional theory: from single-particle degrees of freedom to fission
invited seminar [55 min]

33. Physics Division, Argonne National Laboratory, Lemont, Illinois, USA, 11/19/2012
Covariant density functional theory: addressing the challenges
invited seminar [60 min]

34. National Superconducting Cyclotron Laboratory, Michigan State University, Lansing, USA, 03/12/2013
Covariant density functional theory: from single-particle to collective degrees of freedom
invited seminar [55 min]

35. Institute of Solid State Physics, University of Latvia, Latvia, 05/22/2013
Theoretical nuclear physics in the age of high performance computing
invited seminar [60 min]

36. Department of Technical Physics, Peking University, Beijing, China, 12/23/2013
Rotating nuclei as a probe of covariant density functional theory
colloquium [80 min]

37. Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing, China, 12/25/2013

Single-particle degrees of freedom in covariant density functional theory: successes and challenges
seminar [90 min]

4.3 Presentations of the members of the group at the conferences

1. C. W. Jang
74th Annual Meeting of the Southeastern Section of the American Physical Society, November 8, 2007, Nashville, Tennessee, USA, **Hyperdeformation in the $Z = 40 - 60$ part of nuclear chart**
oral presentation

2. H. Abusara,
Division of Nuclear Physics, American Physical Society, Oakland, US, 10/25/2008, **Recent advances in the study of hyperdeformation at high spin**
oral presentation

3. H. Abusara,
8th International conference on radioactive nuclear beams (RNB8), May 26-30, 2009 Grand Rapids, Michigan, USA, **Hyperdeformation at high spin: general features and the best candidates for observation**
poster

4. H. Abusara, 8th International conference on radioactive nuclear beams (RNB8), May 26-30, 2009 Grand Rapids, Michigan, USA, **Time-odd mean fields and their impact on physical observables**
poster

5. H. Abusara, Division of Nuclear Physics, American Physical Society, Santa-Fe, US, 10/11/2010
Fission barriers in covariant density functional theory
oral talk

6. H. Abusara, National Nuclear Physics Summer School, June 2011, University of North Carolina - Chapel Hill
Fission barriers in covariant density functional theory
poster

7. D. Ray, American Physical Society meeting, April 5-8, 2014, Savannah, Georgia, USA
Nuclear landscape and drip lines in covariant density functional theory
contributed talk

8. D. Ray, Physics Department, S A Jaipura College, 10, Raja Naba Krishna Street, Cal-

cutta - 700 005, India, July 25, 2015
Nuclear landscape and drip lines in covariant density functional theory
seminar

9. S. Agbemava, American Physical Society meeting, April 5-8, 2014, Savannah, Georgia, USA
Global performance of covariant energy density functionals: ground state observables of even-even nuclei and error estimates.
contributed talk

10. S. Agbemava, Division of Nuclear Physics meeting, American Physical Society, Santa Fe, October 27 - October 31, 2015
Single-particle degrees of freedom and pairing properties as sources of theoretical uncertainties in the position of the neutron drip line
contributed talk

11. D. Ray, Division of Nuclear Physics meeting, American Physical Society, Santa Fe, October 27 - October 31, 2015,
Extreme deformations and clusterization at high spin in the $A \sim 40$ mass region
contributed talk

5 Principal Investigator serving as the member of advisory boards of international conferences and workshops

1. 19^{th} Nuclear Physics Workshop "Marie & Pierre Curie", Kazimierz Dolny, September 2012, Poland.

2. 20^{th} Nuclear Physics Workshop "Marie & Pierre Curie", Kazimierz Dolny, September 25-29, 2013, Poland.

3. 21^{th} Nuclear Physics Workshop "Marie & Pierre Curie", Kazimierz Dolny, September 23-28, 2014, Poland.

6 Principal Investigator serving as a chair of the sections at the International conferences or workshops

1. Section "Nuclear structure 10" at the International conference "Nuclear Structure and Dynamics", Dubrovnik, Croatia, May 4-8, 2009.

2. International symposium "Advances in Nuclear Many-Body Theory", Primosten, Croatia, June 7-10, 2011.

3. YIPQS Long-term workshop "Dynamics and correlations in exotic nuclei (DCEN2011)", Yukawa Institute for Theoretical Physics, Kyoto, Japan, September 20 - October 28, 2011

4. 20^{th} Nuclear Physics Workshop "Marie & Pierre Curie", September 25-39, 2013, Kazimierz, Poland

5. The 2^{d} CUSTIPEN Workshop on "Advances in the computational nuclear many-body problem", December 15-17, 2013, Beijing, Peking University, China

6. American Physical Society meeting, April 5-8, 2014, Savannah, Georgia, USA, section "Nuclear Theory II"

7. Fourth workshop "Nuclei and Mesoscopic Physics 2014", Michigan State University, National Superconducting Cyclotron Laboratory, East Lansing, Michigan, USA, May 5-9, 2014

8. Chair of the session "Nuclear structure" at the International conference "Nuclear Structure and Dynamics III", June 14-19, 2015, Portorose, Slovenia