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COLLECTIVE NUCLEAR DYNAMICS

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SHELL CORRECTION AND STABILITY OF HEAVY AND SUPERHEAVY NUCLEI

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Shell effects in the properties of heaviest nuclei are discussed. Such quantities as mass, shape, potential energy surface, fission barrier, α-decay and spontaneous-fission half-lives are examined. Even-even nuclei with atomic number $Z = 90 - 114$ are considered.

A quantitative analysis of already measured properties shows that shell effects decrease masses of heaviest nuclei by up to about 5 MeV. They elongate the α-decay half-lives by up to about 5 orders of magnitude and the spontaneous-fission half-lives by up to about 15 orders of magnitude. This shows a particularly important role of shell effects for heaviest nuclei. Many of these nuclei would simply not exist without shell effects.

Examples of theoretical results are presented. These are the results for shell-correction energy at small (ground-state) deformations of a nucleus and also at large deformations, when fission fragments are already, to large extent, formed. The results for half-lives are also given. They predict relatively long half-lives for nuclei close to the nucleus $^{270}108$ (^{270}Hs), which is expected to be a doubly magic deformed nucleus. Recent measurements seem to support these expectations.

All these results are obtained with the use of the Vilen Strutinski shell-correction method, which is commonly used in the calculations of nuclear mass and its dependence on deformation for nearly 30 years.

VOLUME EFFECTS ON NUCLEAR SHAPE TRANSFORMATIONS

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The dependence of nuclear shape transition on changes in the nuclear volume in ^{24}Mg has been studied within the framework of the constrained finite temperature Hartree-Fock approximation. The deformation parameters β and γ are very sensitive to changes in the nuclear volume. A first-order shape transition in ^{24}Mg takes place at the temperature of 1 MeV and at the volume of $V_c = 1.025\,V_0$, where V_0 is the zero temperature unconstrained volume of the system. We also show that a 2.5 % compression of the system causes the critical temperature of the deformed-to-spherical shape transition to shift downward by 0.7 MeV. Similarly a 2.5 % expansion of the system also yields a decrease in the critical temperature of 0.3 MeV. Meanwhile a compression of the system leads to a corresponding reduction in the magnitude of the level density, while an expansion increases its value only slightly.

NUCLEI AS MULTISKYRMIONS

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Abstract. Last time, thanks to works of Atiyah and Manton, the Skyrme model was given rise to the new development. Making use of the instanton theory, Atiyah and Manton postulated the ansatz expressed the Skyrme field in the form of the holonomy operator. This ansatz allowed the biskyrmion Hamiltonian to be minimized and the deuteron binding energy calculated.

The present lecture is dedicated to the Atiyah - Manton theory review as well as to the original part including the multiskyrmion Hamiltonian quantization by quantum group theory methods. The Hamiltonian eigenvalues lead to the nonlinear mass formula for nuclei

$$M_B M_2 = (M_{B+1} + M_{B-1}) M_1$$

(B is a baryon number). This formula is in well agreement with the experimental data.

Semiclassical periodic orbit theory for the equilibrium deformations and collective dynamics in nuclei

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Numerous calculations of the nuclear masses and deformation energies by the Strutinsky shell correction method show the gross shell structure in deformed nuclei and metallic clusters. The filled shell in nucleon spectrum for the certain nuclear shapes is related to the magic deformed nuclei with increased stability. The explanation of the origin of such phenomena in nuclei can be found in a general semiclassical periodic orbit theory (SPOT) [1-3]. This theory is based on the Feynmann's path-integral method and Gutzwiller's results for the single-particle level density obtained in terms of the periodic orbits in potential well.

We generalised the SPOT to the case of hamiltonians with a symmetry in phase space where continuous families of the classical orbits appear [2]. This approach was applied then to the spheroidal square well potential and deformed harmonic oscillator [3]. In this line an interpretation of nuclear ground state deformations and isomer intermidiate states in fission of nuclei has been done in ref.[3] in terms of the characteristics of classical periodic orbits like their rotation period, degree of the degeneracy and stability. We have found that the first minimum in the double-humped deformation energy is related to the shortest and most degenerate orbits in the plane of the symmetry axis in spheroidal potential well. It has been shown also that the second minimum for large deformations is due to an appearance of the simplest 3-dimensional orbits.

Another application of the SPOT is concerning a study of the gross shell effects in a collective dynamical problem considered within the linear response theory [4]. For the quadrupole vibrations near the spherical shape of nucleus we have obtained the semiclassical shell correction to the nuclear strength function in terms of the classical periodic orbits in potential well. An interference of their contributions to the strength function leads to the two maxima in dependence on the excitation energy which are associated with the giant resonance and low-lying quadrupole state.

The SPOT can be applied for calculations of the quantum shell corrections to macroscopic hydrodynamic-like characteristics of the nuclear large scale dynamics like in the shell correction method. This semiclassical theory is successful for interpretations of the metallic cluster deformations, see [5], and many new phenomena considered in the quantum chaos physics.

References

[1] M.Gutzwiller: J.Math.Phys. **8** (1967) 1979; **12** (1971) 343.

[2] V.M.Strutinsky, A.G.Magner: Sov.J.Part.Nucl. **7** (1976) 138.

[3] V.M.Strutinsky et.al.: Z.Fiz. **A283** (1977) 269.

[4] A.G.Magner, S.M.Vydrug-Vlasenko, H.Hofmann: Nucl.Phys. **A524** (1991) 31.

[5] S.M.Reimann,M.Brack: preprint TPR-93-18, 1993.

ON THE INFLUENCE OF SHELL STRUCTURE IN DEEP INELASTIC HEAVY ION COLLISIONS

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In the microscopical approach [1] a partition of the internal excitation energy between the primary fragments of the binary reactions ^{40,48}Ca(280 MeV)+ ^{248}Cm [2] and ^{40}Ca(340 Mev)+^{238}U [3], ^{48}Ca(425 MeV)+ ^{238}U [4] and between their proton and neutron subsystems are considered. The contributions of the particle-hole excitation and nucleon exchange mechanisms in the transformation of the relative kinetic energy into the internal excitation energy of the dinuclear system are evaluated. Results of the calculation are shown in the Table.

Table 1. Results of calculation of ratios $R_i^{ph/ex} = E_i^{*(ph)}/E_i^{*(ex)}$, $R^{Z/N} = E^{*(Z)}/E^{*(N)}$, $R^{P/T} = E_P^*/E_T^*$ and centroid of the charge distributions $< Z_T >$ in the heavy fragment and its dispersion σ_Z^2 for the reactions ^{40,48}Ca+^{248}Cm and ^{40,48}Ca+^{238}U. $E_i^{*(ph)}$ and $E_i^{*(ex)}$ (i=Projectile, Target) are the intrinsic energy being caused by particle–hole excitation and nucleon exchange mechanisms; $E^{*(Z)}$ and $E^{*(N)}$ are excitation energies of proton and neutron components of nuclei, respectively. $R^{P/T}_{(exp)}$ and $< Z_T >_{(exp)}$ are taken from [3,4].

Reaction	^{40}Ca+^{248}Cm		^{48}Ca+^{248}Cm		^{40}Ca+^{238}U		^{48}Ca+^{238}U	
E_{lab} (MeV	285		285		340		425	
l	3	63	6	61	5	35	4	64
$R_P^{ph/ex}$	0.04	0.16	0.23	0.39	0.19	0.09	0.19	0.17
$R_T^{ph/ex}$	0.11	0.15	0.09	0.18	0.09	0.06	0.06	0.07
$R^{Z/N}$	0.16	0.21	0.82	0.63	0.40	0.30	0.99	0.94
$R^{P/T}$	0.97	1.56	0.98	1.55	0.86	0.85	0.83	0.84
$R^{P/T}_{(exp)}$	$\sim 3.3 \div 5.0$		$\sim 3.3 \div 5.0$					
$< Z_T >$	96.46	96.14	95.86	95.75	93.38	93.26	92.12	92.04
$< Z_T >_{(exp)}$	98.0		96.0		94.5		92.3	
σ_Z^2	3.01	1.82	5.66	3.72	4.63	4.43	6.29	6.16

Neutron number is one of main nuclear quantities which causes a change in shell structure, i.e. proton and neutron binding energies. A change of the mass number of projectile causes strong alteration of the excitation energy distribution between fragments but also between their proton and neutron subsystems. The direction and magnitude of charge centroids shift depends on shell structure and neutron number of nuclei. A nucleon transfer is strongly coupled with dissipation of energy. The thermodynamic equilibrium is not reached in considered reactions.

1. G.G. Adamian, R.V. Jolos, A.K. Nasirov Z. Physik **A347** (1994) 203
2. A. Türler, et al. Phys.Rev. **C46** (1992) 1364
3. R.T. de Souza, et al. Phys. Rew. **C37** (1988) 1901
4. R.T. de Souza, et al. Phys. Rew. **C39** (1989) 114

COLLECTIVE MOTION DAMPING IN THE SECOND POTENTIAL WELL OF FISSIONABLE NUCLEI

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As is known that in the energy surface of heavy nuclei the second potential well exists, where the second class of excited states is realized [1]. The second well states may be populated because of dissipation of fission mode kinetic energy. Taking into account of the probability of the second well state population is necessary to analyze a great body of experimental data on fission of nuclei with double-humped barrier (for example, fission probability [2] and fission time [3] etc.).

The dependencies of this probability on the parameters of fission barrier, excitation energy and magnitude of nuclear dissipation were investigated in the framework of the diffusion model of fission. It was shown that even with the shallow second well and the comparatively high excitation energy the probability of these state population remains sufficiently high (more than 0.6) for all actinide nuclei. Such result is evidence that the second well states can influence greatly the fission dynamics (consequently, fission cross section, fission time, particle multiplicity etc.) even with energy considerably higher than fission barrier. In particular, consideration of the second well state population turns out useful to overcome the "chronic" difficulty in the description of fission probability in the lead region [2].

For further advancement of the concept on fission dynamics it is desirable to measure this probability, namely, the fraction of fission events without population of the second well states. It will be practically direct way to gain information on the magnitude of nuclear dissipation.

References

[1] V.M. Strutinsky, Nucl.Phys., **A95** (1967) 420; **A122** (1968) 1

[2] E. M. Rastopchin, G. N. Smirenkin and V. V. Pashkevich, Z. Phys., **A333** (1989) 389

[3] D.O. Eremenko et al., Nucl. Instr. Meth., **B48** (1988) 216

LEVEL DENSITY OF THE SUPERDEFORMED STATES OF HEAVY NUCLEI

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The transient states of heavy nuclei influence on the many characteristics of the fission process, for example the quasistationary states in the second potential well can influence greatly the fission dynamics and cause increased decay time via the fission channel (τ_f) compared with any other (with emission of neutrons, protons, α-particles and γ-quanta) decay channels (τ_i) [1]. The delay time - $\Delta\tau = \tau_f - \tau_i$ in the fission channel connected with the finite lifetimes of transient excited states in the second potential well is determined by the characteristics of the second well states: $\Delta\tau \simeq \frac{\hbar}{\Gamma_2} = 2\pi\hbar\frac{\rho_2}{N_2}$, where Γ_2 is the total decay width of the second well states and ρ_2 is the level density and N_2 is the effective number of decay channels for the second well states. Information on the decay time characteristics of heavy fissionable nuclei can be obtained by the blocking technique [2].

A new method of extraction of information on ρ_2 for heavy fissionable nuclei from the $\Delta\tau$-values was suggested in ref. [3]. This method is used to extract the $\rho_2(U, J)$ values for nuclei $^{232,233}Pa$, ^{234}U and $^{235,236,238,239}Np$ in excitation energy range from 3 to 12 MeV. Comparison of the level density in the second potential well with one in the first well that was measured in experiment and calculated in the Fermi-gas model, shows that the $\rho_2(U,0)$ are considerable more than the $\rho_1(U,0)$ values for the all investigated nuclei.

The energy dependence of $\rho_2(U,0)$ was analyzed in the generalized superfluid model with allowance for the correlation effects of superconducting type and the coherent effects of a collective nature [4]. Comparison of the calculated data with the experimental values of level density for the all nuclei in question permits one to attribute the observed increase of $\rho_2(U,0)$ related to $\rho_1(U,0)$ to the increased contribution of the effects of a collective nature. These effects arise from the symmetry breakdown of the nuclear shape at large values of deformation. A satisfactory description of the $\rho_2(U,0)$ values for the all investigated nuclei is achieved if the axial and reflection symmetry of the nucleus is assumed to be broken in the excited states of the second potential well.

References

[1] O.A.Yuminov Proc. 14th All-Union Meeting on The Interaction of Charged Particles with Single Crystals, Izd.MGU, 1985, p.68

[2] V.O.Kordyukevich et al., Nucl.Phys., **A492** (1989) 447

[3] S.Yu.Platonov, O.V.Fotina, O.A.Yuminov, Nucl.Phys., **A503** (1989) 461

[4] A.V.Ignatyuk, G.N.Smirenkin, A.S.Tishin, Sov.J.Nucl.Phys., **42** (1985) 569

STATIC AND TRANSITION CHARGE DENSITIES OF THE ISOTOPES OF NEODYMIUM

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The charge densities of the ^{142,146,150}Nd are calculated on the basis of a modified shell model using the formula

$$\rho(r) = \frac{\exp\left(-x^2\right)}{\pi^{3/2} b^3} \sum_{\kappa=0}^{5} f_\kappa x^{2\kappa} \tag{1}$$

where $x = r/b$, b is oscillator parameter. The coefficients f_κ are obtained by allowing fractional occupation numbers of the states 2s, 2p and 1h. We have obtained very good agreement with experimental data [1] with the occupation probabilities of the states 2s, 2p and 1h equal to 0.7, 0.4 and 0.2 respectively. Deformation of the nucleus and contribution of the first 2^+ - states to charge densities were taken into account on the basis of the simple collective Bohr-Mottelson model. Our calculations for ^{146}Nd and ^{150}Nd describe experiment better than calculations on the basis of DDHFB model. For ^{142}Nd these calculations have been conducted for the first time. Transition charge densities of dipole states of the ^{146}Nd (1_1^-) and ^{150}Nd (1_1^- and 1_2^-) are calculated on the basis of the schematic model [2]

$$\rho_1(r) = N\left[\left(3r^2 - \frac{20}{3} < r^2 >\right)\frac{d\rho(r)}{dr} - 5r\rho + \frac{3}{4m^2\omega_0^2}\Delta\rho(r)\right] \tag{2}$$

where $\frac{1}{m\omega} = b^2$. The microscopic model satisfactorily describes all oscillations of the model-independent transition densities. At the same time hydrodynamic (Bohr-Tassie and Steinwedel-Jensen), scaling approximation and quasi particle phonon model contradict experimental data [1].

We find that the contribution of the low lying dipole states in the energy weighted sum rule is less than 1%.

[1] R.K.J. Sandor, Shape Transition in the Nd-Isotopes (thesis). Verdhoven, 1991.
[2] G. Orlandini, S. Stringeri, and M. Traini. Phys. Lett. B119, 21, 1982.

THOMAS-FERMI TREATMENT OF NUCLEAR MASSES, DEFORMATIONS AND DENSITY DISTRIBUTIONS

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Abstract

A recently completed Thomas-Fermi model of nuclei is described. Six adjustable parameters of the effective nucleon-nucleon interaction were fitted to the shell-corrected binding energies of 1654 nuclei and to the diffuseness of the nuclear surface. The model is then successful in reproducing nuclear sizes, and only small deviations are found between calculated and measured fission barriers of 36 nuclei. The model is then applied to the prediction of fission barriers of light elements, to drip-line nuclei like ^{82}Sn and ^{170}Sn, to the properties of nuclear and neutron matter and to nuclear bubble configurations with $Z^2/A = 100$. The relation of a Thomas-Fermi theory to the Droplet and Liquid Drop models is illustrated.

NUCLEAR LEVEL DENSITY IN HOT NUCLEI

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To investigate the variation of the nuclear level density parameter, a, with temperature we have developed a model which simultaneously includes, in a realistic way, many important effects: surface diffuseness, the continuum, the space variation of the momentum and the frequency dependent effective masses, and shell effects. The temperature dependence of these effects and of the mean field is also accounted for by the model. The main ingredient in determining the parameter, a, is the single particle level density, $g(E)$, calculated for the finite mean field using a semi-classical method. The semi-classical method for calculating $g(E)$ was tested by comparing the semi-classical values of $g(E)$ with the smooth quantum mechanical values of $g(E)$, obtained by applying the Strutinsky smoothing procedure to the exact quantum mechanical results for $g(E)$. Using this model we have calculated the mass and the temperature dependence of the parameter, a, and compared the results with recent experimental data.

Space Parity Violation as a Probe of Mass Asymmetric Deformations in the Process of Slow Neutron Induced Fission.

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Space parity nonconservation effect in neutron induced fission[1] (PNC-effect) consists in existence of an angular distribution asymmetry of fragment separation relative to the direction of neutron polarization.

One of the main suppositions of the modern PNC-effect theory[2,3] involve the specific role of the Bohr's transition states near the top of external fission barrier. Here the correlation of pear-shaped deformed nucleus axis and the fissioning nucleus spin is formed for a short time. If the descent process is adiabatic and the pear-shaped deformation axis is conserved along the way to the scission point the PNC-correlation neutron spin and light (heavy) fragment momentum will be observed and the proper asymmertry coefficient ($\sim 10^{-4}$) is expected to be independent on the main fragment characteristics ($\sim 10^{10}$).

All known experimental data about PNC-effect in fission are discussed in this lecture as a new way to study low exitation energy fission.

References

1. G.V.Danilian, Sov. Phys. Usp **23** (1980) 323.
2. O.P.Sushkov and V.V.Flambaum, Sov. Phys. Usp **25** (1982) 1.
3. V.E.Bunakov and V.P.Gudkov, Nucl.Phys. **A401** (1983) 93.

TERNARY FISSION DYNAMICS

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The study of the light charge particle (LCP) accompanied fission process or ternary fission is closely connected with common problems of large scale collective motion of nuclear matter. Investigations of ternary fission give possibility to measure the most short time intervals and determine the dynamic parameters at the descent from saddle point and near scission point configuration. Connections between dynamic properties of fissioning nucleus and characteristics of ternary fission are analysed in the framework of dynamical model of ternary fission [1-3]. The mechanism of LCP formation at the late stage of fission is governed by the fission dynamics at the descent from the saddle to scission point. Near the scission point the ternary nuclear system (TNS) is formed. The mass and charge distributions of LCP are determined at the initial stage of TNS evolution. Classical consideration of three body dynamics at the late stage of TNS evolution is used to calculate kinematic characteristics of LCP and obtain important information about scission point configuration. Results of theoretical calculations of mass, charge, energy and angular distributions distributions of LCP are in a good agreement with experimental data. The further improvement of theoretical model is connected with consideration of quantum effects and fluctuations due to fission modes and channels.

References

1. V.A. Rubchenya, Sov. J. Nucl. Phys., 35 (1982) 334

2. V.A. Rubchenya, S.G. Yavshits, Z. Phys., A329 (1988) 217

3. A.S.Roschin, V.A.Rubchenya, S.G.Yavshits , Yad. Fiz. (Sov.J.Nucl. Phys.) 53 (1991) 1475.

FISSION RATE OVER A MULTIPLE-HUMPED BARRIER: LANGEVIN APPROACH

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The problem of the fission probability in presence of double-humped barrier seems first had been considered by Bjornholm and Strutinsky in ref. [1]). Their solution formed the basis of the statistical model approach to the analysis of the data. Recent experiments on prescission light particle multiplicities [2]) revealed that the traditional statistical modelling of the fission process is insufficient. The standard statistical model has to be modified by incorporating dynamical ingredients. Some progress in this direction has been obtained recently by matching a dynamical (Langevin-Monte-Carlo) description with a properly modified statistical model [3]). A dynamical model is unavoidable in the initial stage of the fission process until a quasistationary flow over the barrier is established; then a regime is reached when a statistical description makes sense. The crucial quantity for matching the dynamical approach with the statistical model is the quasistationary fission rate. In order to make sure that this matching is performed in a consistent way one has to show that the longtime limit of the decay rate calculated dynamically is in agreement with the decay constant used in the statistical model description of the process. Recently the solution of the problem has been obtained for the situation, where the fission process of hot nuclei is governed by the entropy which has a single-humped barrier [4]).

The problem of consistency between LFDD and the statistical model in describing the decay from a multiple-humped barrier occurs in particular for fission of actinide nuclei at moderate excitation energies (10-40 MeV), when shell effects still play a significant role and multichance fission is of importance. Multiple-humped barriers also appear for other regions of Z and A if the temperature is not too high, so the single-humped barrier should be considered rather as an exception [5]). Using the collective rotational enhancement factor of the level density in constructing the entropy gives in addition to shell effects rise to multiple-humped structures of the fission barriers [6]).

In the present contribution we derive an analytical formula for the quasistationary decay rate over a multiple-humped barrier and present the comparison between the statistical and dynamical decay rates in the case of a double-humped barrier with and without competing decay modes. The results obtained with the analytical formulas are shown to be in good agreement with the longtime limit of the dynamical decay rate obtained by means of Langevin-Monte-Carlo simulation. The agreement is proved explicitly for double-humped barriers of different shapes.

References

1) S.Bjornholm and V.M.Strutinsky// Nucl.Phys. **A136** (1969) 1
2) D.Hilscher and H.Rossner// Ann.Phys.Fr. **17** (1992) 471
3) P.Fröbrich, I.I.Gontchar, N.D.Mavlitov// Nucl. Phys. **A556** (1993) 281
4) I.I. Gontchar, P.Fröbrich, N.I. Pischasov// Phys.Rev. **C47** (1993) 2228
5) V.V.Pashkevich// Int. Sch.-Sem. on HI Phys., Alushta 1983, Dubna, JINR D7-83-644, p.405
6) I.I. Gontchar, P. Fröbrich// to be published

ON DISTRIBUTION OF EMISSION TIMES IN EVAPORATION-FISSION REACTIONS

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It is known for some time /1,2/ that calculations involving particle separation energies from spherical composite nuclei strongly overestimate the multiplicities of protons and α-particles emitted in (quasi)fission reactions. In order to remove this discrepancy Lestone /2/ has proposed to take into consideration the shape dependence of separation energies. With an additional assumption that particle emission is most intensive in configurations close to the scission point he has obtained a good description of the data on light particle multiplicities for the composite nuclei with $A \approx 200$.

In the present work the shape-dependent separation energies were introduced in the particle emission calculation for the system $^{60}Ni +^{100} Mo$ at $E < 10MeV/A$ studied in /3/. The shape of the system as a function of time was calculated by the model of dissipative collisions /4/. New separation energies have lead to somewhat better description of particle yields but the extent of the disagreement remains still very large. The reason of this weak influence has been traced back to the fact that shape corrections to separation energies are only significant at the very beginning of the collision ($t < 10^{-21}s$) and toward the moment of the neck rapture ($4 \times 10^{-20}s$) while particle emission takes place mainly within the interval $10^{-21} - 10^{-20}s$, that is between these two extremes.

References

1. Aleshin V.P. J.Phys.G: Nucl.Part.Phys. 19 (1993) 307-317
2. Lestone J.P. Phys.Rev.Lett. 70 (1993) 2245-2248
3. Gonin M. *et al* Phys.Rev. C42 (1990) 2125-2142
4. Feldmeier H.T. Rep.Prog.Phys. 50 (1987) 915-994

GROUND STATE CORRELATIONS AND CHARGE TRANSITION DENSITIES

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It is well known that many basic features of the nuclear vibrational states can be described within the Random Phase Approximation (RPA), which enables one to treat some correlations in the ground state. Being the spatial overlap between the ground state wave function and the excited state wave function the charge transition density provides a good test for nuclear models. Recent experimental and theoretical (based on the RPA)) studies [1] of the charge transition densities to investigate the interplay between single-particle and collective degrees of freedom in the excitation of the low-lying states in some spherical nuclei are in reasonable agreement, but the theory gives fluctuations of the transition densities in the interior region. In RPA, as in the Hartri-Fock approach, the theoretical fluctuations are too large in the nuclear interior, which indicates a systematic problem of a more fundamental nature.

The effect of ground state correlations on the charge transition densities of vibrational states in spherical nuclei has been studied in our recent paper [2]. The problem for the ground state correlations (GSC) beyond RPA leads to a non-linear system of equations, which is solved numerically. The influence of the correlations on the pairing is taken into account too. The selfconsistent inclusion of GSC beyond RPA results in an essential supression of the charge transition density in the nuclear interior in comparison with the RPA calculations and enables one to reproduce the experimental data.

[1] R.J.K. Sandor et al., Nucl. Phys. **A535** (1991) 669

[2] D. Karadjov, V.V. Voronov and F. Catara, Phys. Lett. **B306** (1993) 197

NEW APPROACH TO PARAMETRISATION OF FISSION FRAGMENT MASS DISTRIBUTION

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The simple quasiphenomenological model for description mass distribution fragments of fission heavy nuclei is suggested in which the process of fission has two independent stages.

A nucleus when moving to the saddle point is possessing of consecutively a series of configurations at the first stage.

The formation of fragments and breaking away when the nucleus is sloping from the saddle point to the scission point takes place at the second stage.

Taking into account the above suppositions and that the mass-asymmetrical deformation can be taken as a value which is connected with ratio of volumes of the right and left fragments the mass distribution can be described as a product of two probabilities corresponding to the first P_A and the second T_F processes

$$Y(A) = P_A T_F.$$

In the frames of this approach it was carried out the analysis of mass distributions of spontaneously fissioning nuclei ^{252}Cf, ^{253}Es, $^{254,256,258}Fm$; compound nuclei formed in reactions with thermal neutrons ^{230}Th, $^{234,236}U$, ^{240}Pu, ^{255}Es, $^{256,258}Fm$; and $^{239,240}Pu$ nuclei formed in reactions with α-particles of various energy.

The expressions for P_A and T_F probabilities were obtained and the dependence of its parameters on excitation energy was found for some nuclei.

A good fit with experimental data is obtained, when describing mass distributions of fission fragments, some discrepancies are mainly based on pairing effects which is not accounted in this simple approach.

The comparative analyses of theoretical descriptions using five Gaussians and our descriptions showed that the fit with experimental data is approximately equal (in limits of statistical errors).

One can note that the used expression is based on some suppositions about processes taking place in the fissioning systems and influencing on formation of fragments mass distribution and has twice less number of variable parameters. The good agreement with experimental data shows that the method of description of fragments mass distributions of heavy fissioning nuclei is valued.

ACTINIDE NUCLEI FISSION AT MEDIUM EXCITATION ENERGIES

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The fission of actinide nuclei at medium excitation energy has a number of peculiarities. Even at low excitation energy there is an appreciable contribution from emission fission, i.e. from the fission following the emission of one or several neutrons. This fact complicates the interpretation of observed angular distributions. Apart from this, in the interaction of charged particles of medium energy with heavy nuclei there is a noticeable contribution of direct processes into the total reaction cross-section σ_R, which depends upon the energy and type of bombarding particles.

In the present paper the results of the analysis of energy dependence of fission cross-sections, mass distributions and the ratio of symmetrical and asymmetric fission yields are presented for the interaction of ^{3}He and ^{4}He ions with some actinide nuclei in the wide energy ranges. The particular attention in this analysis was directed to the contribution of processes preceding the formation of fissioning system. An account of the emission fission and inelastic process contribution into fissile nucleus production cross section enabled to extract from experimental data an energy dependence of K_0^2 values well consistent with theoretical calculation results on the basis of superfluid model. It was shown, that at excitation energies above 45 MeV the influence of shell model effects is suppresed and the nuclear fission is determined by liquid-drop barrier.

One of interesting and insufficiently explored problems in the fission physics is connected with the investigation of a role played by shell effects in the formation of fragment mass distributions during a nuclei fission. The asymmetry of fragment mass distributions in the spontaneous and low energy fission of actinide nuclei is usually associated with exhibition of fragment shell structure during the nucleus motion from saddle to scission point. Experimental data on fission product mass distributions of the same fissionable nuclei indicate that at excitation energies above 45 MeV the ratio of symmetric and asymmetric fission yields is almost equal and this equality practically does not change with energy increase. Statistic model analysis of these data show a difference disappearance of fission barrier values for symmetric and asymmetric fission modes at this excitation range.

There is a spectrum of transition states at fission barrier which basic characteristic are the collective energy and the total angular moment. Dependence of integral and differential cross sections on total angular moment was well-known but its influence on description of fission fragment mass distributions was not taken into account. A simple method of description of fission fragment mass distributions with a dependence from total angular moment of a fissioning nucleus was proposed. The measurements and analysis of large number of experimental data for fission of some actinide nuclei formed in reactions with neutrons, deutrons, α-particles an γ-rays with the same excitation energy but different total angular moment was carried out. The energy dependence of the dispersion of fission fragment mass distributions on temperature and total angular moment of fissioning nucleus was obtained. A good description of studied experimental data was achieved within framework of this method and with common set of parameters. Obtained results testify that taking into account the influence of total angular moment for description of fragment mass distribution for fission of heavy nuclei is necessary.

ON THE MACROSCOPIC LIMIT OF COLLECTIVE MOTION

by

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We study nuclear collective dynamics within linear response theory. Strength distributions of isoscalar modes will be shown at different temperatures, both for "adiabatic" as well as for "diabatic" conditions, but taking into account the effects of collisional broadening. It will be demonstrated that vibrations about thermal equilibrium have the very characteristic feature of the strength being concentrated in a low frequency mode, provided the temperature exceeds some critical value. Such a behaviour can be simulated by applying "Strutinsky-smoothings" to response functions. The results can be analyzed in terms of the transport coefficients for average motion, namely effective stiffness, inertia and friction. The latter is examined in detail. It will be shown how Strutinsky smoothing may simulate the macroscopic limit. Depending on details of treating collisions, for friction such a limit may either resemble the wall formula or the hydrodynamic case. An important issue is the temperature dependence, in particular the question to which extent conventional Strutinsky smoothing becomes equivalent to "temperature smoothing".

THOMAS FERMI APPROXIMATION TO THE LINEAR RESPONSE FUNCTION

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The linear response and density-density correlation functions are given in Thomas–Fermi approximation. It is shown that this is valid at intermediate and high momentum transfers. The equivalence to a Strutinsky averaged response function is demonstrated. Applications to inelastic electron-nucleus and proton-nucleus scatterings are presented. Inclusion of 2p-2h states in TF approximation is discussed.

In a somewhat different context, in a hot finite Fermi system the statistical fluctuations of one body observables are of importance. They will be calculated from a TF approximation to the matrix of variance-covariance of the fluctuating phase space distribution. The relevance with respect to heavy ion collisions is indicated.

NUCLEAR FERMI-LIQUID DROP MODEL

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The essential peculiarity of the nuclear liquid is the Fermi motion of the nucleons. This aspect plays an important role in the consistent description of the equilibrium and dynamic properties of the nuclear liquid drop.

The equilibrium ground state of the Fermi-liquid drop (FLD) is described in the extended Thomas-Fermi approximation using the effective Skyrme forces. The Fermi surface deformation is not essential in that static case and the theory leads to quite good values for the ground state energy and equilibrium space density of nucleons [1].

The dynamic properties of the nuclear FLD depend in many aspects on the Fermi surface distortion in the phase space. This manifests itself as an increase of the deformation potential energy when the shape of the nucleus varies in time and should be taken into consideration in the fission of the nuclei or during collision of heavy ions. The allowance for the dynamical Fermi surface distortion gives rise to the possibility of the excitation in a nuclear Fermi liquid of the transverse wave which is absent in the simple liquid drop model of nucleus. This means specifically that the nucleus behaves as an elastic, isotropic solid body during collective motion [2].

The dynamical distortion of Fermi surface leads to some features of damping mechanism at the FLD collective motion. The damping contains the retardation effects which depend on the nuclear temperature. The theory gives a reasonable description of the nuclear viscosity and describes the transition from zero sound (collisionless) regime to the first sound (hydrodynamic) regime in hot nuclei [3].

The deformation of Fermi surface may play an appreciable role in the formation of particle emission spectra. The direct non-statistical emission (splashing) of nucleons is possible due to the dynamical deformation of Fermi surface accompanying the collective motion of nucleus. The FLD model gives the relative contributions of the evaporation and cold emission of particles dependently upon the magnitude of nuclear friction coefficient.

References

[1] V.M.Kolomietz: *Local density approach for atomic and nuclear physics.* Kiev: Naukova Dumka, 1990.

[2] V.M.Kolomietz. Sov.J.Nucl.Phys. **37** (1993) 325.

[3] V.M.Kolomietz, A.G.Magner and V.A.Plujko. Z.Phys. **A345** (1993) 131; **A345** (1993) 137.

LARGE AMPLITUDE MOTION-COUPLED QUADRUPOLE AND MONOPOLE VIBRATIONS

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The set of nonlinear dynamical equations for quadrupole (Q_{20}) and monopole (Q_{00}) moments of nuclei is derived from the equation for Wigner function $f(\mathbf{r},\mathbf{p},t)$ with the help of the method of Wigner function moments [1]. We use the simple model Hamiltonian:

$$H = \frac{p^2}{2m} + \frac{m}{2}\omega^2 r^2 + \lambda\, q(t)\, Q(\mathbf{r}),$$

where $q(t) = \int d\mathbf{r} \int d\mathbf{p}\, Q(\mathbf{r})\, f(\mathbf{r},\mathbf{p},t)$, $\quad Q(\mathbf{r}) = x_1^2 + x_2^2 - 2x_3^2$. The system is:

$$m^2\ddot{Q}_{00} + 2m^2\omega^2 Q_{00} + 4\lambda\, m\, Q_{20}^2 - 2\,\Pi_{00} = 0,$$

$$m^2\ddot{Q}_{20} + 2m^2\omega^2 Q_{20} + 4\lambda\, m\,(2\,Q_{00}\,Q_{20} - Q_{20}^2) - 2\,\Pi_{20} = 0,$$

$$\dot{\Pi}_{00} + m^2\omega^2\dot{Q}_{00} + 2\lambda\, m\,\dot{Q}_{20}\,Q_{20} = 0$$

$$\dot{\Pi}_{20} + m^2\omega^2\dot{Q}_{20} + 2\lambda\, m\left(2\,\dot{Q}_{00}\,Q_{20} - \dot{Q}_{20}\,Q_{20}\right) = 0.$$

where $\Pi_{20} = \Pi_{11} + \Pi_{22} - 2\Pi_{33}$, $\quad \Pi_{00} = \sum_{i=1}^{3} \Pi_{ii}$, $\quad \Pi_{ii}(t) = \int d\mathbf{r} \int d\mathbf{p}\, p_i^2\, f(\mathbf{r},\mathbf{p},t)$,

$Q_{20} = J_{11} + J_{22} - 2J_{33}$, $\quad Q_{00} = \sum_{i=1}^{3} J_{ii}$, $\quad J_{ii}(t) = \int d\mathbf{r} \int d\mathbf{p}\, x_i^2\, f(\mathbf{r},\mathbf{p},t)$.

These equations are solved numerically for ^{208}Pb. It turns out that the functions Q_{20}, Q_{00}, Π_{20} and Π_{00} oscillate irregulary, the oscillation amplitudes being strongly dependent on the initial conditions. Their Fourier analysis yields about 30 eigenfrequencies with different strengths. The low-lying 2^+ states, the giant quadrupole and monopole resonances and the corresponding two-phonon states are reproduced very well. The most of high-lying states have the multiphonon nature.

[1] Balbutsev E.B. Particles and Nuclei, v.22(2), p.159, 1991.

Configuration Dependent Fluctuation Analysis Tested on ^{163}Er

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The decay of high spin rotational nuclei can be studied by a Fluctuation Analysis Method (F.A.M.) recently developed and applied so far to γ-γ coincidence spectra of normally deformed nuclei in the rare earth region. The method allows us to obtain information on the average properties of the nuclear rotational motion, related to the number of paths the nucleus effectively follows decaying through different decay modes to the ground state.

With the new generation of multi-detector arrays it is now possible to collect extremely high statistic triples and higher fold γ coincidences. This offers the possibility of selecting specific single particle configurations, like for example super-deformed states or discrete rotational bands built on high K orbitals. The measurement of the fluctuations associated to these configurations is expected to give information on the coupling of the single particle states to the quasi-continuum. This type of analysis has been applied to a rich data set on ^{163}Er displaying discrete rotational bands with high K values very weakly populated ($\approx 8\%$ of yrast intensity) at an excitation energy of more than 1 MeV above yrast, i.e. in a region where the damping of the rotational motion is expected to play an important role, and where the nuclear residual interaction is strong enough to mix the nuclear single particle states.

The data have been collected with the multidetector array GA.SP (Legnaro, Italy) in the standard configuration. The reaction used was ^{18}O on ^{150}Nd with a 87 MeV beam energy and a 700 $\mu g/cm^2$ target. A total of more than 6×10^9 triple events was collected.

The Fluctuation Analysis Method was applied to the ^{162,163,164}Er γ-γ spectra both for the analysis of the ridges and of the central valley. A number of paths in the order of 30 has been extracted from the first ridge, in addition to those used for constructing the level scheme (subtracted out), suggesting that 30 unresolved two-step rotational bands have still to be found in the energy region below $U_0 \approx 800$ KeV. Above 800 KeV the number of two step rotational bands, extracted from the valley, is much higher ($N^{(2)}_{path} \approx 10^5$) , in agreement with the rotational damping picture and with the results previously obtained applying the F.A.M. on nuclei in the same mass region and with comparable deformations (^{168}Yb ^{158}Hf and ^{163}Tm). The number of paths in the valley from γ-γ spectra gated on discrete transitions belonging to the high-K bands K1, K2 and on the newly found band K4 was also extracted and found to be an order of magnitude smaller. This shows for the first time that the intensity of the fluctuations is strongly dependent on the single particle configuration selected, and it will be demonstrated how it is possible to select weakly populated high K states out from a background of the strongly populated normally states, by means of the Fluctuation Analysis Method.

MACROSCOPIC PROPERTIES OF SURFACE EXCITATIONS IN A FERMI LIQUID

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The surface excitations in a semi-infinite Fermi liquid are studied within a semiclassical approach. The Landau-Vlasov equation for a Fermi system with a moving free surface is used [1]. It is found that the inertial and dissipative properties of the surface excitations in a Fermi liquid are related to anisotropic dynamic distortions of the Fermi sphere [2]. The velocity field shows the vortex behaviour. The expression for the friction coefficient is the same as found within the one-body dissipation theory (the wall formula). It is also found that the hydrodynamical pressure comes from the momentum-dependent interaction [3]. This interaction gives rise to an essential contribution to the inertial parameter. To take into account the two-body interactions a collisional integral is included within the improved relaxation time approximation. An interplay, due to the self-consistency, between one-body damping and the collisional one results in decreasing of the friction coefficient.

References

1) V.I. Abrosimov and J. Randrup, Nucl. Phys. A449 (1986) 446; *ibid* A489 (1988) 412.
2) V.I. Abrosimov and V.M. Kolomietz, Phys. At. Nucl. 56(9) (1993) 1208.
3) V.I. Abrosimov and V.M. Kolomietz, Nucl. Phys.A (1994) in press.

CRITERIA OF QUADRUPOLE VIBRATIONAL INSTABILITY OF NUCLEUS FROM EQUATIONS OF NUCLEAR FLUID DYNAMICS

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Based on equations of the nuclear fluid dynamics taking into account elastic-like behavior of nuclear response we obtain the following formula for eigenfrequencies of electro-capillary nuclear vibrations [1]:

$$\omega_L^2 = \frac{C_L}{B_L} = \frac{4\sigma}{mn_o R^3}(L-1)(2L+1) - \frac{8\pi q_z^2 n_o}{3m}\frac{(L-1)(3L+1)}{(2L+1)}. \quad (1)$$

From (1) it follows the critical ratio $\frac{Z^2}{A} = 35$ against 49 predicting the standard Liquid Drop Model (LDM) with parameters entered in eq.(1) taken from [2]. Fig.1 displays a comparison of Fluid Dynamical Model (FDM) and LDM. It is seen that the FDM predicts the lost of stability of quadrupole vibration (the start point of fission) for nuclei with $A > 230$, whereas the standard LDM for nuclei with $A > 380$.

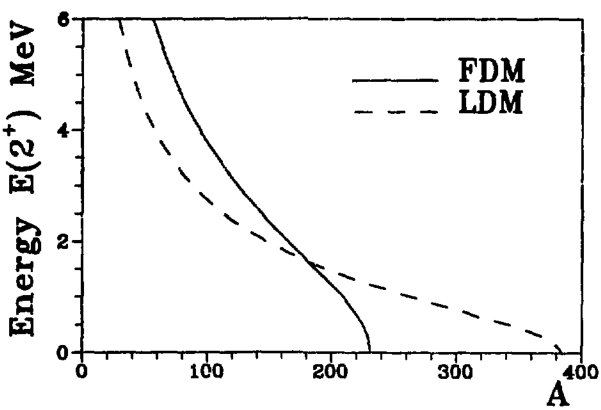

Fig. 1. Energy of fission quadrupole mode vs mass number.

REFERENCES

[1] S.I.Bastrukov, I.V.Molodtsova, and E.Yuldashbaeva *Rus.J.Nucl.Phys.* **57** (1994) 93.
[2] A. Bohr and B. Mottelson, *Nuclear Structure* Vol.2. (Benjamin, New York, 1975).

THE GIANT MULTIPOLE RESONANCE WIDTHS IN HEATED NUCLEI BASED ON THE VLASOV–LANDAU KINETIC EQUATION

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Damping of nuclear collective vibration is studied within the framework of the Vlasov-Landau equation including retardation (memory) effects in the collision integral. The expressions for the nuclear viscosity and the width of the giant multipole resonances in a heated nucleus are obtained by taking into account quadrupole dynamic distortion of the Fermi surface. These expressions allow for a transition between the regimes of rare and frequent two-body collisions. An interpolation formula for the width is proposed in which allowance for all multipolarities of the distortion of the Fermi sphere is made. The width of the giant dipole resonance as a function of excitation energy is calculated using this formula for the Sn nuclei region. The results for the width variation with temperature are in a qualitative agreement with the experimental data. They show a smoother behavior with increasing temperature compared to that of the zero sound model.

On the Specific Features of Fluid Dynamic Model of Heavy Ion Collisions and Emission of the Light Particles at Intermediate Energies

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As is known the light particles emission gives important information of the mechanism of interaction of complex nuclei. For the description of this reaction some different models were suggested: cascade, thermodynamic, direct reaction models and so on. Our approach deals with the idea hot spot, advanced by H.A. Bethe in 1938 [1].

At present the methods of computation of various processes of nucleus- -nucleus interaction have reached a considerably high level [2,3]. However, for the complete understanding of the phisical picture of nucleus-nucleus interactions in the energy region, some additional research is necessary. An example is the fast particles source with the velocity equal to one half of projectile velocity.

It is of interest, that integration variable averaging results in the form [4]

$$d^2\sigma/d\Omega dE \sim \sqrt{E} exp(-(E - \sqrt{EE_0}\cos\theta)/T), \qquad (1)$$

which corresponds to availability the source of the fast particles moving with the velocity equal to one half of projectile beam according to experimental data.

The Fermi liquid effects are described by simplified equations within the framework of the long mean free path fluid dynamics [5]. Further natural development of this approach was the combining of two models: "non-collisional" fluid dynamics [6] and conventional local equilibrium fluid dynamics [7], derived in [8] according to Bertsh's parametrization [9].

Satisfactory agreement with experimental double differential cross sections $d^2\sigma/d\Omega dE$ of secondary particles (nucleons and fragments) emission for small and large angles have been obtained.

1. Bethe H.A., Phys. Rev., 1938, v. 53, p. 267.
2. Stocker H., Greiner W. Phys. Rep., 1986, v. 137, p. 277.
3. Mishustin I.N., Russkikh V.N., Satarov L.M., Yad. Fiz., 1991, v. 54, p. 429.
4. D'yachenko A.T., Proc. Int. School-Seminar on Heavy Ion Physics, Dubna, May 10-15, 1993, v. 2, p. 233.
5. Kolomietz V.M., Kollektivnaya yadernaya dinamika, Leningrad, Nauka (in Russian), 1990, p. 67.
6. D'yachenko A.T., Rubchenya V.A., Eismont V.P., Izv. Akad. Nauk SSSR, ser. fiz., 1981, v.45, pp.767;2070.
7. Wong C.Y., McDonald J.A., Phys. Rev., 1977, v. C16, p.1196.
8. D'yachenko A.T., Izv. Akad. Nauk SSSR, ser. fiz., 1987, v.51, p.902.
9. Bertsh G., Z. Phys., 1978, v. A289, p. 103.

SURFACE RESPONSE IN THE FERMI-LIQUID DROP

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Isoscalar quadrupole vibrations at finite temperature have been discussed in [1]. There the nucleonic dynamics has been described with a shell model but taking into account the effects of collisions. It was found that with increasing temperature the collective dynamics seems to reach a "macroscopic" limit. In the present work this limit is studied within the Fermi-Liquid model. This model follows the phase-space approach put forward in [2]: A Landau-Vlasov equation with collision term is used to describe the motion of the nucleons in the interior, supplemented by appropriate boundary conditions on the deformed nuclear edge within a sharp surface approximation. The collision term was treated in relaxation time approximation but retardation effects were accounted for by letting the relaxation time τ depend both on frequency ω as well as on temperature T:

$$\tau^{-1} = \tau_0^{-1}(T^2 + 3(\hbar\omega)^2/4\pi^2) \tag{1}$$

with τ_0 being constant.

For quadrupole vibrations around a spherical shape we have obtained a collective response function $\chi_{coll}(\omega)$ of the form:

$$\chi_{coll}(\omega, T) = -\frac{\kappa^2}{B(\omega,T)\omega^2 + i\omega Z(\omega,T) - C(\omega,T)} \tag{2}$$

Here, $B(\omega,T)$,$C(\omega,T)$ and $Z(\omega,T)$ are functions of frequency and temperature. If evaluated near the poles they correspond to the mass parameter, stiffness and friction coefficient respectively. The κ is a coupling constant related to static properties of the selfconsistent mean field. For zero temperature the form (2) represents one giant quadrupole resonance corresponding to the collisionless regime of the zero sound: $\omega\tau >> 1$. With increasing temperature the strength of this resonance shifts to lower frequencies. For temperatures larger than about $3-4MeV$ the hydrodynamic, collision dominated regime is reached with $\omega\tau << 1$ and only one peak of the strength distribution survives, like in [1]. For any temperatures $T \neq 0$ the two poles of the response function (2) appear as two different excitation modes. One of them is on the imaginary axis of the complex plane of ω and corresponds to an overdamped motion. Other pole belongs to the path in the ω -plane which connects the giant resonance pole with the hydrodynamic low frequency one for underdamped excitations. The transparent description of these two modes has been suggested in terms of the macroscopic transport cofficients.

References

[1] H.Hofmann, S.Yamaji, A.S.Jensen. Phys. Lett. **B286** (1992) 1.

[2] V.M.Kolomietz, A.G.Magner and V.A.Plujko. Z.Phys. **A345** (1993) 131.

ON THE DECAY OF THE COMPOUND NUCLEUS

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A highly excited compound nucleus decays mainly by emission of n, p and α and by nuclear fission. A detailed understanding of the competition between the different decay modes implies that the dependence of the evaporation probability on the deformation of the compound nucleus and its angular momentum is carefully studied.

We present a new approach to the evaporation theory which is based on the Thomas-Fermi approximation. First numerical results show that the average transmission coefficient depends rather strongly on the nuclear deformation and rather weakly on the rotational frequency.

Coulomb Excitation of the odd-odd nucleus ^{180}Ta

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The level structure of the rare odd-odd nucleus $^{180}_{73}$Ta$_{107}$, surviving in nature in an excited isomeric 9^- state is important for an assessment of its astrophysical relevance. Excitation of the isomer with real photons (photoabsorption) and with virtual photons (Coulomb-excitation) indicate the presence of excited levels that decay by an appreciable fraction to the 8 h ground state. Both experiments used activation techniques. We here report on matrix elements in the rotational band built on the 9^- isomer measured by in-beam Coulomb excitation of an enriched target.

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EXCITED COLLECTIVE STATES IN THE NUCLEI AROUND Z≃50 CLOSED PROTON SHELL

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Low energy excitation states of odd nuclei with the number of nucleons close to magic one are a classic example of quasi-particle levels in nuclei. Excitation of vibration states in even-even nuclei is usual at these energies. However, such a clear picture disappears at high excitation energies and at large angular moments introduced. The observed quasi-rotation bands in ^{112,114,116,118}Sn [1] which indicate on a considerable deformation of "spherical" nuclei at high excitations are a good illustration to this fact.

A rather complicated interconnection of quasi-particle, vibration and rotation modes is observed. Such a situation has evoked a considerable interest of theoreticians and experimenters for investigation of nuclei in this region.

A lot of works devoted to this problem appeared. In one of the last investigations [2] an attention was paid to measurements of the probability of transitions between levels which gives a possibility to investigate in details the nature of levels in a large range of excitation energies.

The results of analysis of excited collective states in nuclei with Z≃50, as well as its interpretation using different theoretical models, including non-traditional approach of the dynamic collective model (DCM) [3], are given in this paper. It was shown that a large volume of experimantal data can be described by a single manner within DCM frames.

1. S.Bron et al. Nucl. Phys., A318(1979)335;
2. I.N.Vishnevsky et al. Izv. AN. Kaz. SSR, ser.fiz., 2(1989)64; Ukr. Fiz. Jurn., 36(1991)1132; Ukr.fiz.Jurn.,36(1991)982; Izv. AN SSSR, ser. fiz., 55(1991)2166.
3. G.B.Krygin, V.E.Mitroshin. Thes.rep. of the Meeting on nuclear spectroscopy and atomic nucleus structure, Leningrad, Nauka, 1991, p.125.

THE MICROSCOPIC DESCRIPTION OF GIANT RESONANCES IN STABLE AND UNSTABLE NUCLEI.

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The main (and rather old!) problems of the microscopic theory of giant resonances in cold nuclei are the description of their widths, fine structure and decay characteristics. It is clear that one can not solve the last two problems reliably without solving the widths problem.

Such a microscopic approach which takes into account, in addition to the RPA configurations, the single particle continuum and complex 1p1h+phonon configurations has been developed for magic nuclei [1]. It is based on the consistent use of the Green function method and uses the well known Landau-Migdal phenomenological interaction with the same parameters for all the nuclei under consideration. To account of the rest of the configurations and the experimental resolution, a constant smearing parameter equal to this resolution has been used. The calculations for isoscalar and isovector E0, E1, E2, M1 resonances in ^{40}Ca, ^{48}Ca, ^{208}Pb gave reasonable agreement with experiment for integral characteristics, including widths, and also for the fine structure of the isoscalar E2 resonance in ^{208}Pb [1,2,3].

The approach has been applied to giant resonances in unstable magic nuclei. Thus we have predicted characteristics of the above-mentioned resonances in ^{56}Ni, ^{78}Ni, ^{100}Sn and ^{132}Sn.

The consistent treatment of the ground state correlations caused by 1p1h+phonon configurations explains the following experimental results: 1) the large strength below 14 MeV and splitting of the isoscalar E2 strength in ^{40}Ca; 2) the M1 resonances in ^{16}O and ^{40}Ca which are absent in the RPA approach [4]; and 3) the characteristics of the low-lying 1+levels in the (3602-4132) keV interval for ^{96}Zr. These correlations also give a noticeable additional isoscalar E0 strength in ^{208}Pb at (6-12) MeV and in ^{40}Ca at (7-14) Mev [2] and some other effects.

We have obtained the first results of the generalization of this approach applied to: 1) non-magic nuclei; 2) hot magic and non-magic nuclei; and 3) fine structure of giant resonances via a "refined" optical potential. The last improvement will allow one to calculate the fine structure more consistently than with the use of the smearing parameter. The calculations are now in progress.

1. S.Kamerdzhiev, J.Speth, G.Tertychny and V.Tselyaev, *Nucl.Phys.* **A555**, 90 (1993).
2. S.Kamerdzhiev, G.Tertychny and J.Speth, *Nucl.Phys.* **A569**, 313c (1994).
3. S.Kamerdzhiev, J.Speth, G.Tertychny and J.Wambach ,*Z.Phys.* **A346**,353 (1993).
4. S.Kamerdzhiev and V.Tkachev, *Phys.Lett.* **B142**, 225 (1984); *Z.Phys.* **334**, 19 (1989).

The γ- decay of highly rotating nuclei: From discrete bands to damped rotational motion

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Information on the nuclear structure of rotating nuclei is usually obtained identifying the E2 transitions in rotational bands near "yrast", while the γ-rays emitted from levels at higher excitation energy form the so called "quasi-continuum" spectra, in which the individual transitions are not distinguished because of the high level density and finite detector resolution. Ridge and valley structures characterise 2-dimensional energy spectra of resolved and unresolved γ-rays. The firsts are due to the γ-transitions of rather cold rotational bands, the seconds are due to γ transitions originating at higher excitation energies.

At high excitation energy, rotational bands become very closely spaced and any single band can be viewed as a collective sequence of related states imbedded in a dense background of other, more or less complicated states, to which it will couple by residual interaction. This coupling leads to the stationary states of the system, the compound states, which are complicated mixtures of the available unperturbed configurations. The rotational degree of freedom is damped in these compound states, in the sense that the electric quadrupole decay of a single state with angular momentum I will not go to a unique final state with angular momentum I-2, but to a set of states described by a strength function. The shape of the strength function depends on the strength of the residual interaction.

A satisfactory connection between theory and experiment needs a simulation of the decay cascades followed by the application ofthe same analysis procedures to the calculated and measured spectra. Experimental and simulated spectra of the nucleus ^{168}Yb are presented and discussed to point the important role of the residual interaction acting among the rotational bands. The results, although preliminary, indicate that it should be possible to describe quantitatively the transition between the domain of discrete and statistical γ- spectroscopy.

EXCITATION OF A QUANTAL AND A CLASSICAL GAS IN A TIME-DEPENDENT POTENTIAL

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The computer simulations of oscillating Woods-Saxon or cavity potentials filled with either a classical or a quantal gas of independent particles have been done. We have now available of the order of 600 excitation histories of such gases undergoing usually one period of oscillation (but sometimes several), classified according to frequency and multipolarity of the oscillation and the degree of diffuseness of the potential. We are still in the process of displaying and interpreting some of the results, but certain important features are already apparent. A notable finding is that contrary to concerns sometimes voiced in the literature the classical wall formula does not fail catastrophically when confronted with quantal calculations. This is true even for relatively small systems - in our case 112 neutrons in doubly degenerate eigenstates. On the contrary, the wall formula, in addition to reproducing accurately the classical computer simulations, gives also an approximate account of the quantal results in the regime where it is expected to be valid, namely for not too small oscillation frequencies and not too large surface diffuseness.

Coupling Between Slow and Fast Degrees of Freedom in Systems with Complex Spectra

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We consider many-body systems which display slow modes and have complex spectra of intrinsic states, such as atomic nuclei, atomic clusters, deformable cavities, and so forth. The effects of the coupling between the intrinsic and the slow degrees of freedom is analyzed, by assuming random matrix properties for the intrinsic degrees of freedom, and that the time evolution of the slow degrees of freedom modifies the intrinsic configuration of the system. By neglecting the reaction of the intrinsic degrees of freedom on the slow modes, we derive (and solve) evolution equations for intrinsic state population probabilities, the average excitation energy and its fluctuations. These evolution equations are characterized by strong memory effects, and only in the long time limit the dynamics becomes Markovian.

INTERACTION OF COLLECTIVE AND NON-COLLECTIVE MODES IN STRONGLY INTERACTING FERMIONIC SYSTEMS

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Transport properties of strongly interacting fermionic theories are investigated in order to understand the microscopic basis of diffusion, dissipation and decorrelations of states. One of the purposes is to establish the conditions of complexity under which one can replace the interactions of collective and non-collective modes with a stochastic heat bath. In formulating the problem of the interaction of collective and non-collective degrees of freedom, we have found that there are surprising and new phenomena which can arise due to these interactions. Just beyond the adiabatic limit is a regime which is characterized by anomalous diffusion. This is a class of diffusion processes which are not described by the standard Fokker-Plank equation, and is seen both in semi-quantum and full coupled channel quantum calculations. We attempt to classify different transport limits of collective dynamics in terms of the spectral properties of the many-body Hamiltonian. Using new extensions of random matrix theory, as well as semi-quantum and fully quantum treatments of the collective dynamics, we are able to suggest new phenomena which exist just beyond the conventional adiabatic limit. A relation between chaos, and different transport limits is suggested.

Microscopic theory of nuclear giant resonances

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While the general properties of nuclear giant resonances are rather well established, much more uncertainties exist about their microscopic structure. What is the role played by single nucleons in building up the nuclear collective motion? To answer this question, a unique tool is the study of particle decay of giant resonances. Experimental measurements of such decay are now available and can provide severe tests for theoretical models.

We have developed a fully microscopic theory of the excitation and damping of giant resonances. Self-consistency is one of the characteristics of the model, which has as only phenomenological input an effective nucleon-nucleon interaction. The aim is to understand up to what degree of accuracy these effective interactions are able to reproduce detailed properties of the collective motion. A number of results for both isoscalar and charge-exchange excitations of the nucleus ^{208}Pb will be discussed.

EXTENSION OF THE QPM TO $T \neq 0$ BASED ON THE FORMALISM OF THE THERMO FIELD DYNAMICS

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We formulate an approach to the problem of a width of a giant dipole resonance in hot nucleus based on the extension of the quasiparticle – phonon nuclear model (the QPM) [1] to $T \neq 0$ using the formalism of the thermo field dynamics [2,3]. According to the prescriptions of the TFD one has firstly to double formally the number of nuclear degrees of freedom by introducing the so-called tilde states in addition to the ordinary Fock states and then making the thermal Bogoliubov transformation to the thermal quasiparticles $\beta^+_{jm}, \tilde{\beta}^+_{jm}, \beta_{jm}, \tilde{\beta}_{jm}$. The coefficients of the thermal Bogoliubov transformation coincide with the thermal Fermi occupation numbers of the usual Bogoliubov quasiparticles. Knowing the coefficients one derives the thermal Hamiltonian $\mathcal{H}$ of the QPM expressed in terms of thermal quasiparticles and thermal RPA-phonons $Q^+_{\lambda\mu i}, Q_{\lambda\mu i}$ which consist of forward going and backward going thermal biquasiparticle components.

$$\mathcal{H} = \sum_{\lambda\mu i} \omega_{\lambda i}(Q^+_{\lambda\mu i}Q_{\lambda\mu i} - \tilde{Q}^+_{\lambda\mu i}\tilde{Q}_{\lambda\mu i}) - \mathcal{H}_{\beta Q}$$

Here $\omega_{\lambda i}$ is the energy of the thermal phonon state. The structure of $\mathcal{H}_{\beta Q}$ in terms of thermal quasiparticles and phonons is quite similar to that of the quasiparticle – phonon interaction at $T = 0$ [1]. It mixes the states with different numbers of phonons and to diagonalize $\mathcal{H}$, one has to include both one- and two- thermal phonon components in the trial wave function. Then using the variational principle one can derive the following equation for the energies $\eta_{J\nu}$ of these complex states

$$det|(\omega_{Ji} - \eta_{J\nu})\delta_{ii'} - \frac{1}{2}\sum_{\lambda_1 i_1 \lambda_2 i_2} \frac{U^{\lambda_1 i_1}_{\lambda_2 i_2}(Ji)U^{\lambda_1 i_1}_{\lambda_2 i_2}(Ji')}{\omega_{\lambda_1 i_1} + \omega_{\lambda_2 i_2} - \eta_{J\nu}}| = 0$$

The quantity $U^{\lambda_1 i_1}_{\lambda_2 i_2}(Ji)$ stands for the coupling matrix element of one- and two- thermal phonon states and depends only on the phonon structure and Fermi thermal occupation numbers. The above equation is very similar to that for $T = 0$ [1]. In contrast with the approach of [4] Bose thermal occupation numbers can not appear in this formalism naturally. In other words, although our thermal phonons are built from "thermal" quasiparticles, the system of interacting phonons isn't heated itself.

1. Soloviev V.G. "Theory of atomic nuclei: quasiparticles and phonons" (Institute of Physics Publishing, Bristol and Philadelphia, 1992)
2. Tanabe K., Phys.Rev. C., 1988, **37**, 2802; Hatsuda T., Nucl.Phys., 1989, **A492**, 187
3. Vdovin A.I., Kosov D.S., JINR, Preprint E4-93-417, Dubna, 1993;
   Kosov D.S., Vdovin A.I., JINR, Preprint E4-94-106, Dubna, 1994
4. Bortignon R.A. et al., Nucl.Phys., 1986, **A460**, 149;
   Kamerdziev S.P. Preprint FEI-1860, Obninsk, 1987

DIRECT NEUTRON DECAY OF GIANT RESONANCES

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The theoretical description of partial nucleon escape widths of various giant resonances (GR) seems to be a serious test of nuclear structure models. The particle-hole basis is apparently best suited for the description, because most of final states populated after the GR direct nucleon decay can be simply described by using this basis. Therefore, the continuum-RPA can be used for the description of particle-hole states (doorway states) corresponding to a given GR. A method for calculating the GR strength function, i.e. for calculating the energy, total nucleon escape width, fraction of the relevant sum rule, transition density of the doorway states has been long formulated within the continuum-RPA [1,2]. The method for calculating the S-matrix of nucleon scattering via virtual excitation of GR has been formulated recently [3]. In particular, this method allows one to calculate the partial nucleon escape widths of the doorway states. The nuclear mean field and particle-hole interaction are input data for the methods mentioned above. The doorway-state coupling to many-particle configurations can be phenomenologically taken into account in calculations of energy-averaged reaction amplitudes on the basis of reasonable statistical assumptions [3]. Thus, the calculated partial nucleon escape widths of the GR can be directly compared with the relevant experimental data.

Bearing in mind the known (and expected) experimental data, we calculated the partial neutron escape widths of the isoscalar monopole and isovector dipole GR's [3], the partial proton widths of the isobaric analog [4] and Gamov-Teller [3] resonances for several medium and heavy nuclei. A phenomenological (shell-model) mean field of the Saxon-Woods type and a Landau-Migdal particle-hole interaction have been used in mentioned calculations. A special attention is given for the description of partial cross sections of the semidirect photonucleon reactions [5]. A peculiarity of this description lies in the fact that an essential gross structure appears in any RPA calculations of the strength function of the isovector dipole giant resonance. In particular, this method allows one to calculate the partial nucleon escape widths of the doorway states.

[1]S.Shlomo and G.Bertsch. Nucl.Phys. **A243**(1975)507

[2]F.A.Gareev et al. Sov.J.Nucl.Phys.**33**(1981)337

[3]S.E.Muraviev and M.H.Urin. Nucl.Phys.**A569**(1994)267c; A572(1994)No.2

[4]O.A.Rumyantsev and M.H.Urin. Phys.Rev.**C49**(1994)537

[5]M.H.Urin and G.A.Chekomazov, Izv.RAN (ser.fiz.) to be published

GIANT RESONANCE FINE STRUCTURE

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Microscopic calculations of the fine structure of giant resonances for spherical nuclei will be presented. Excited states are treated by wave function that takes into account coupling of simple one-phonon configurations with more complex ones [1]. Nuclear structure calculations are applied to description of the γ-decay of resonances into low-lying states and the relativistic Coulomb excitation of the double resonances.

As an example, we consider γ-decay properties of the High Energy Octupole Resonance (HEOR) in ^{90}Zr [2]. In our calculation, the HEOR has the energy centroid $E_x = 22.4$ MeV and the total width $\Gamma = 4.4$ MeV. The total width $\Gamma_{HEOR \to 2^+_{1,4}, 4^+_{1,2}}$ is equal to 3 keV or about 10% of the GDR γ-decay width into the ground state. It opens a new possibility to investigate the HEOR.

For the first time the relativistic Coulomb excitation of the double giant resonance in ^{136}Xe is calculated based on the microscopic structure of the GDR [3]. Second order perturbation theory is used to describe the excitation process. It is found that the two-phonon cross section is essentially equal to that of the non-interacting phonon model and that the associated width is 1.5 times the width of the one-phonon resonance. Calculated and experimental [4] cross section (in mb) for the excitation of the single GDR, GQR$_{is}$ and GQR$_{iv}$ and the double $[\mathrm{GDR}\otimes\mathrm{GDR}]_{0^+,2^+}$ resonances are presented in table. The results of calculations are strongly dependent on the minimal value of the impact parameter $R_{min} = r_o(A_t^{1/3} + A_p^{1/3})$ used and the ones in table are obtained with $r_o = 1.5 fm$. While the predictions associated with the one-phonon states provide an overall account of the experimental findings, the calculated cross section for the two-phonon states is much smaller than that extracted by the involved analysis of the data.

GDR	GQR$_{is}$	GQR$_{iv}$	GDR+GQR$_{is}$+GQR$_{iv}$	$[\mathrm{GDR}\otimes\mathrm{GDR}]_{0^+ + 2^+}$
1480	110	60	1650	50
1024 ± 100	–	–	1485 ± 100	215 ± 50

[1] V.V. Voronov and V.G. Soloviev, Sov. J. Part. Nucl., **14** (1983) 583
[2] V.Yu. Ponomarev and V.V.Voronov, JINR E4-93-334, Dubna, 1993
[3] V.Yu. Ponomarev et al., Phys. Rev. Lett. **72** (1994) 1168
[4] R. Schmidt et al., Phys. Rev. Lett. **70** (1993) 1767

THREE-CLUSTER APPROACH TO THE ^9Li NUCLEUS STRUCTURE

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The recent years progress achieved in the experimental techniques made it possible far from the drip line nuclei investigation [1]. This stimulates further development of the theoretical notions of their properties and, in particular, of neutron-rich light nuclei ones.

Due to its extraordinary features, of special interest now is the ^{11}Li nucleus. Usually it is regarded as a three-cluster system $^9Li+n+n$. Therewith it is assumed that the ^9Li nucleus may be described in the framework of the usual shell model which feasibility is not apparent in this case. Therefore it is worthwhile to study the ^9Li nucleus structure on the basis of more general, than the standard shell model, cluster approach.

In this work the ^9Li properties were studied in the resonating group method framework [2] under assumption that this nucleus has a three-cluster structure $\alpha + t + {}^2n$. Variational calculations of the ground state energy E_{min} have been performed. In calculations nucleon-nucleon interaction potentials V_{N-N} of Hasegava - Nagata (H-N) [3] and Volkov (second set, V2) [4] have been used. In each of the cases oscillator radius r_0 was chosen to reproduce binding energies of free α-particle E_α and triton E_t. At such choice of r_0 di-neutron turnes out unbound up to 2-2.5MeV due to excess of the internal kinetic energy. This excess has been subtracted from the internal di-neutron energy $E_{^2n}$, lowering it up to ~ 0, and has included into the cluster relative motion kinetic energy. In the case of Volkov potential mixture parameter m was 0.53 to obtain the two-neutron separation energy S_{2n}.

V_{N-N}	r_0, fm	E_α, MeV	E_t, MeV	$E_{^2n}$, MeV	S_{2n}, MeV	E_{min}, MeV	$r_{\alpha-t}$, fm	$r_{\alpha-{}^2n}$, fm	$r_{t-{}^2n}$, fm	$E^{(0)}_{min}$, MeV
H-N	1.47	-28.1	-6.84	0.0	5.36	-38.6	2.18	0.75	2.17	-36.5
V2	1.50	-28.0	-7.06	0.0	6.15	-44.3	2.76	2.22	2.94	-38.9

Results of calculations are presented in the Table, where, apart from already mentioned values, the shell model limit of the ^9Li ground state energy $E^{(0)}_{min}$ and the most probable distances between α-particle and triton $r_{\alpha-t}$, between α-particle and di-neutron $r_{\alpha-{}^2n}$ and between triton and di-neutron $r_{t-{}^2n}$ are indicated too. In spite of the fact that results for two potentials are somewhat different, it is obviously that the ^9Li ground state is not adequate to the shell model limit and has pronounced three-cluster structure.

REFERENCES

1. Detraz C., Vieira D.J. Annu.Rev.Nucl.Part.Sci.,1989,v.39, p.407.
2. Filippov G.F. Riv.Nuovo Cim.,1989,v.12,p.1.
3. Hasegawa A., Nagata S. Prog.Theor.Phys.,1971,v.45, p.1786.
4. Volkov A.B.Nucl.Phys.,1965,v.74, p.33.

VARIATIONAL CALCULATION OF THE ^{6}He GROUND STATE IN THE THREE-CLUSTER RESONATING GROUP METHOD APPROXIMATION.

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The modern three-particle models, which are applied to the neutron-rich nuclei (^{6}He) investigation, offer two basic shortcomings: using the effective core-N interactions and approximate ways of the Pauli principle treatment.

In this work the ^{6}He cluster structure was studied in the algebraic version of the resonating group method framework [1] under assumption that this nucleus has a structure $\alpha + n + n$. At first we carried out the simplest (variational) calculation of ^{6}He ground state energy E_{min} and corresponding geometric configuration but with the correct explicit Pauli exclusion principle taking into account.

In calculations nucleon-nucleon interaction potential of Volkov (second set, V2) [2] have been used. The oscillator radius r_0 was chosen to reproduce the binding energy of free α-particle. Since the oscillator radius was fixed according to the compact particle binding energy, then the di-neutron (if it to form) is underbinding up to 2-2.5 MeV. Therefore its internal energy forced to modify as well as in work [3].

The calculations show that at any choice of mixture parameter m the absolute minimum of the total ^{6}He energy is reached for the binary configuration $\alpha +^2 n$. Finally, $m = 0.62$ have been chosen to reproduce the experimental value of two-neutron separation energy $S_{2n}^{(exp)} = 0.975 \pm 0.040$MeV.

V_{N-N}	r_0, fm	E_α, MeV	$E_{^2n}$, MeV	S_{2n}, MeV	E_{min}, MeV	$r_{\alpha-^2n}$, fm	$r_{\alpha-n}$, fm	r_{n-n}, fm	$E_{min}^{(0)}$, MeV
V2	1.38	-28.0	0.07	0.98	-28.9	3.37	-	-	-11.7
			-	0.56	-28.5	-	2.30-3.05	4.61	

Results of calculations are presented in the Table, where, apart from already mentioned values, the shell model limit of the ^{6}He ground state energy $E_{min}^{(0)}$ and the most probable distances between α-cluster and di-neutron $r_{\alpha-^2n}$ for the binary configuration (upper line), and between α-cluster and each of the neutrons $r_{\alpha-n}$ and between neutrons r_{n-n} for the linear three-cluster configuration (lower line) are indicated too.

From the presented results it is seen that the comparatively simple calculation with precise Pauli principle treatment and suitable choice of the N-N interaction potential permits to describe the main properties of the ^{6}He nucleus and that the cluster configuration in this nucleus is more profitable by the energy than the shell model one (E_{min} is considerable lower then $E_{min}^{(0)}$). The existence of the total internal energy two minimums, more deep one corresponds to the binary case and the less deep one corresponds to the three-cluster configuration, indicates that the probability of the first configuration is greater than the second one and this result is in a good agreement with the conclusions of the other authors (Zhukov et al.)

REFERENCES

1.Filippov G.F. Riv.Nuovo Cim.,1989,v.12,p.1.
2.Volkov A.B.Nucl.Phys.,1965,v.74, p.33.
3.Filippov G.F. Posdnyakov Yu.A, Verbitsky V.P. previous page

Collective States of Even-Even and Odd Nuclei with $\beta_2, \beta_3, \beta_4, ..., \beta_N$ Deformations

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A macroscopic model [1] is developed for description of energy levels belonging to even and odd rotational bands together with reduced probabilities of dipole crossband and quadrupole interband transitions in soft even-even and odd nuclei with $\beta_2, \beta_3, \beta_4, ..., \beta_N$ deformation. This model is a generalization of the Davydov-Chaban model [2] taking into account only quadrupole deformation of nuclei and of our previous model [3,4] considering only nuclei with both quadrupole and octupole deformations to the case of nuclei with $\beta_2, \beta_3, \beta_4, .., \beta_N$ deformations.

Simple expressions for the energy levels of even and odd rotational bands in even-even and odd nuclei are obtained in [1,3-4]. The influence of shape stretching due to rotation of the nucleus on energy levels and reduced probabilities is considered.

Different macroscopic calculations of polarized electric dipole moment are discussed [5]. It is shown that this dipole moment depends on the position of the center of mass of nucleus with quadrupole and octupole deformations. The conditions of consistency of the radii of the proton and neutron surfaces and potentials are discussed. These conditions must be incorporated in a shell-correction calculation of dipole moment [5]. Strong dependence of the polarized electric dipole moment on the angular dependence of neutron skin thickness is discussed.

The comparison of experimental and theoretical energy levels and ratios of reduced probabilities for isotopes $Ra, Th, Ac, Rn, Sm, Pm, Ba, Ce$ is performed. The agreement between calculated and experimental values are good.

REFERENCES

1). V.Yu. Denisov and A.Ya. Dzyublik , Submitted for publication.
2). A.S. Davydov and A.A. Chaban, Nucl. Phys. **20** (1960) 499.
3). A.Ya. Dzyublik and V.Yu. Denisov, Phys. At. Nucl. **56** (1993) 303.
4). V.Yu. Denisov and A.Ya. Dzyublik, Phys. At. Nucl. **56** (1993) 477.
5). V.Yu. Denisov, Sov. J. Nucl. Phys., **55** (1992) 1478.

POLARIZATION EFFECTS IN NUCLEI

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We consider some electromagnetic processes caused by the nuclear polarizability. Firstly, this is well-known appearance of the induced electrical dipole moments in quadrupole-octupole deformed nuclei. As a consequence, electrical dipole radiation becomes possible with the energy which is the sum of the energies of the quadrupole and octupole nuclear phonons. This prediction agrees well with the experimental data concerning hard non-statistical gamma rays from fission fragments.

Secondly, the condition of the fixity of the c.m. of the nucleus gives rise to the electrical dipole moments in the nuclei of the condenser type. That manifests itself in anomalous conversion of the E1 type. In usual atoms contribution of the condenser moments to internal conversion happens to be lower than from the electrical polarization moments because of small probability to find an electron inside the nucleus. But in muonic atoms their contribution becomes predominant. Our calculation agrees with the experimental data concerning muon shake effect in the fragments from muon-induced prompt fission, giving the shake probability around 0.5 percent.

Then, nuclear polarization in the nucleus-nucleus collisions lowers the fusion barriers and enlarges the curvature of the potential barrier. Use of the Goldhaber-Teller model of the giant dipole resonance allows the analytical solution within the multidimensional approach. The calculated lowering of the fusion barrier e.g. in the case of the ^{248}Cm + ^{48}Ca fusion reaction is about 0.5 MeV. Taken together with the change of the curvature of the barrier, that makes the cross-section several times higher.

Finally, the role of the low-lying collective states is illustrated by the example of the pygmy-resonances. Although they exhaust only a small part of the energy-weighted sum rule, their moments turn out to be comparatively high, as the calculation within the Steinwedel–Jensen model shows.

NOTE ABOUT EFFECT OF INDEPENDENT PARTICLE MOTION AND COLLECTIVE NUCLEAR DYNAMICS ON INELASTIC FORMFACTORS IN 180° ELECTRON SCATTERING

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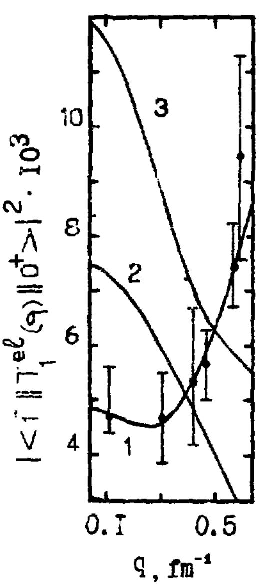
Alternative concepts about a nuclear dynamics can lead to similar results. In particular, when describing the E1 transitions in nuclei the close relationship between the Goldhaber-Teller (GT) model of the oscillating proton and neutron spheres and the shell model is established [1]. However, the calculation of the formfactor of the giant resonance (FGR) in the nucleus ^{16}O in electron scattering at 180° for the excited configuration $(1p)^{-1}(1d,2s)^{1}$ (the hole is in 1p-shell) shows the q dependence (1) of FGR which is opposite to the predictions (2) of GT model for the momentum transfer q>0.2 fm^{-1} [2]. This contrariety stimulated our calculation (3) in the independent-particle model with three-shell wave functions of the excited mixed configurations [3]. Just the same physical situation (the transition of a nucleon from 1p- to (1d,2s)-shell) in the two calculations leads to the alternative results. The character of the q dependence (3) of FGR is in agreement with [1] also for the scattering angles θ<180°. Thus the account of the electron scattering data [2] much more likely will require further efforts perhaps at the cost of taking into consideration the meson-exchange currents.



[1] D.M.Brink. Nucl.Phys., 4, 215 (1957).
[2] G.J.Vanpraet. Ibid., 74, 219 (1965) and references therein.
[3] A.V.Fursayev, V.K.Tartakovsky. Physics in Ukraine Intern. Conf.:Proc.(Nucl.Phys.), Kiev, June 22-27, 1993.- Kiev: Bogolyubov ITP, 1993.-P.54-57.

THE INTERNAL CONVERSION AND e^+e^--PAIRS CREATION FROM THE HEATED NUCLEI

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At the sufficiently high nuclear excitation energies the processes of the interaction of nuclei with the electromagnetic field can be considered statistically. The rate of these processes is determined by the probability of γ-radiation from the heated nuclei. This enables to investigate the dynamics of the heated nuclei through detecting of the γ-quanta, e^+e^--pairs and internal conversion electron. The general expressions for the probabilities of the last two processes are found for an arbitrary multipolarity $\lambda > 0$ of the γ-transitions. The probabilities of the e^+e^--pair creation $\bar{W}_{e^+e^-}$ (T) and K-shell ionization $\bar{W}_e$ (T) are calculated in the statistical Weisskopf model as a function of the nuclear temperature T. The temperature dependent conversion coefficient for the internal pair creation $\beta_{e^+e^-}(T) = \bar{W}_{e^+e^-}(T)/\bar{W}_\gamma(T)$,where $\bar{W}_\gamma(T)$ is the E1 γ-transition probability in the Weisskopf model, increases with increasing T. This coefficient is of the order of 10^{-3} at $T >> m$ (m is the electron mass). The analogous quantity for the K-shell ionization process $\beta_e = \bar{W}_e(T)/\bar{W}_\gamma(T)$ increases with decreasing T and has the form

$$\beta_e(T) = \frac{1}{3}\alpha^4 Z^3 x^2 exp(x)[x(\frac{3}{2}K_1(x) - K_2'(x)) + (1-2x)K_2(x)]$$

where $x = m/T$, α is the fine-structure constant, Z is the nuclear charge, $K_n(x)$ is the Macdonald function.The quantity $\beta_e(T)$ is equal to 10^{-2} at T=0.2 MeV for heavy nuclei with $Z \sim 100$.

β-DECAY in HOT SOLIDS

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The *brilliant* Strutinsky's approach has been applied recently to study various properties of the electrons in mesoscopic systems and solids. We consider in this contribution the valence electron excitations accompanying β-decay. These phenomena result in some decreasing of the β-radioactivity rate (ξ_β) due to shifting of the β-spectrum end-point. Neglecting Coulomb effects in decay process we can estimate with semiclassical accuracy the reduction factor a as: $a = \frac{\xi_\beta}{\xi_{\beta,0}} \approx (1 - <\epsilon> / E_\beta)^5$, where $\xi_{\beta,0}$ and E_β are the β-radioactivity rate and the β-transition energy for the bare nucleus; and $<\epsilon>$ is the *mean excitation energy of electron gas. Some various theoretical approaches* here are usually based on the Hartree method, neglecting the correlation effects in the electron dynamics. These methods are reasonable in the low temperature limit and give very small reduction effect: $(1 - a) \precsim 10^{-2}$. However, for systems at finite temperature the correlations, reflecting the inexactness of the Hartree method and associated with the deviation of the true interaction from the self-consistent one, become very important.

The powerful physical framework to include these effects is provided by utilization Strutinsky's smoothing concept for the description of the excitation process [1]. Then the correlation as well as thermodynamic fluctuation effects can be taken into account in phenomenological way by using the Langevin equation of motion for semiclassical electron dynamics. This approach gives *surprise* of the resonant behaviour of the excitation process [2] as a function of temperature (T), *which* results in *curiously* strong anomalous reduction effect (see *fig.*).

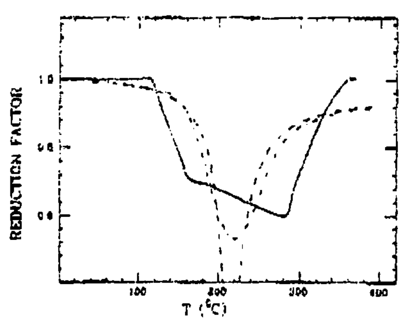

Fig. Temperature dependence of the β-radioactivity rate reduction factor a (see text) of tritium absorbed in titanium. Full line represents the data [3], dashed lines are the results of calculations according to uniform distribution of valence electrons in matter, and dashed-dotted line is the Local Density Approximation with model [4] for electron density.

References

[1] V.N.Kondratyev Phys.Lett. **A179** (1993) 209

[2] V.N.Kondratyev Preprint INFN-LNS, 23.02.94; and Phys.Lett. **A** (1994) in press

[3] O.Reinfenschweiler Phys.Lett. **A184** (1994) 149

[4] N.M.Kabachnik, V.N.Kondratyev, O.V.Chumanova Phys.Stat.Sol. (b) **145** (1988) 103

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PROBABILITIES OF β-TRANSITIONS IN DYNAMIC COLLECTIVE MODEL

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The expressions for the reduced matrix elements of Hamiltonian of weak interaction for the U-mode decay (β^--decay of odd-neutron nuclei and β^+-decay of odd-proton nuclei) and V-mode decay (β^--decay of odd-proton nuclei and β^+-decay of odd-neutron nuclei) have been obtained in the framework of dynamic collective model [1]. The influence of the zero vibrations of the nuclear shape as well as the different effects of noncommutativity of one-quasiparticle and collective modes to the probabilities of β-transitions is taken into account.

β^+-decay of the $^{111,113,115}Sb$ is considered. It has been found that the dependences of log ft on the number of diagrams accounted for are the same for all Sn isotopes although the component compositions of the wave functions of populated states vary significantly with the change of mass number.

1.G.B.Krygin, V.E.Mitroshin // Fiz. Elem. Chastits At. Yadra. -1985.-V.16.-P.927.

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REFRACTIVE EFFECTS IN ELASTIC SCATTERING OF ^{11}Li BY LIGHT DEFORMED NUCLEI AT 29 MeV/NUCLEON

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At present there exist very recent data for elastic scattering of exotic ^{11}Li nuclei on light deformed nuclei at 29 MeV/nucleon. The elastic differential cross section exhibit the pronounced smooth structure and no diffractive oscillations within angular range $\theta = 8 - 21°$. The available data were analyzed by means of scattering matrix formalism, using a parametric form of the partial-wave S-matrix [1]: $S(L(\Omega)) = \exp[-2\delta_0(L(\Omega))+2i\delta_1(L(\Omega))]$, $2\delta_j(L) = \mu_j[2L\Delta_j\varphi(L) + \Delta_j^2\varphi^2(L)]^{1/2} \times f^{j+1}(L, L_j, \Delta_j)$, $\varphi(L) = -f^{-1}(L, L_j, \Delta_j)\ln[1 - f(L, L_j, \Delta_j)]$, where Ω is the solid angle, $j = 0,1$; $f(L, L_j, \Delta_j)$ is the two-parameter Fermi function. ^{28}Si nuclei were treated as rigid rotors and scattering amplitudes of Ref.[1], including terms of order $(\beta_2)^2$, were used. The values of $L_0 = 37.799$, $L_1 = 31.218$, $\Delta_0 = 9.689$, $\Delta_1 = 22.860$, $\mu_0 = 0.225$ and $\mu_1 = 1.075$ were derived for $^{11}Li + {}^{28}Si$ system at 319 MeV. Deformation parameter was taken to be $\beta_2 = -0.24$ [1]. The parameter values should be regarded with caution, because the experimental data is available only for a rather limited angular range, excluding the exponential-like decrease of cross section. We also analyze elastic scattering data for $^{6}Li + {}^{28}Si$ at 25.7 and 35 MeV/nucleon and extrapolate the resulting S-matrix parameters to 29 MeV/nucleon, thereby providing comparison with $^{11}Li + {}^{28}Si$ system and consideration of the effects associated with the presence of neutron excess.

Certain features seem to be established: (1) Strong absorption radius $R = 7.4$ fm for $^{11}Li + {}^{28}Si$ is of comparable magnitude to that for $^{6}Li + {}^{28}Si$ at the same energy per nucleon. (2) The diffuseness $d_1 = \Delta_1/k = 2.4$ fm (k is the wave number) for $^{11}Li + {}^{28}Si$ is about 70% larger than that for $^{6}Li + {}^{28}Si$ system. This may be attributed to the manifestation of neutron halo. (3) The decrease of transparency parameter with increasing neutron excess is more than 30%. (4) The strength of refraction is larger for neutron-rich ^{11}Li nuclei than for ^{6}Li projectiles mainly due to increase of refraction parameter μ_1 by about 12% with neutron excess.

1. A.V. Kuznichenko, A.S. Molev, G.M. Onyshchenko. Izv. Acad. Sci.of Russia 57 (1993) 152.

DAMPING OF GIANT MONOPOLE RESONANCES WITHIN A LINEARIZED LANDAU-VLASOV DYNAMICS

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Isoscalar monopole vibrations in spherical nuclei are studied within the Landau-Vlasov dynamics [1,2]. Energy and strength of the giant monopole resonance (GMR) are well reproduced. The Landau damping of the monopole vibrations is analyzed [3]. It is found that the local Fermi surface corresponding to the GMR is deformed. The collision integral is included within the relaxation time approximation. The found total width is too small to explain the observed one in heavy nuclei. Because the Landau damping is sensitive to the effective nuclear force the missing part of the width can be connected to certain properties of the latter.

References

1) D.M.Brink, A.Dellafiore, and M.Di Toro, Nucl. Phys. A456 (1986) 205.
2) V.Abrosimov, M.Di Toro, and A.Smerzi, Z. Phys. A347 (1994) 161.
3) V.Abrosimov, M.Di Toro, and V.Strutinsky, Nucl. Phys. A562 (1993) 41.

$2\beta\nu$ decay and SU(4) symmetry violation in nuclei

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To present time the calculations of $2\beta 2\nu$ decay rates have been performed by different author for a great many of nuclei [1]. The main shortcomings of mentioned calculations are: (i) essensial dependence of calculated values on model parameters and, as a consequence, significant distinction of results obtained by different author [1]; (ii) the use in calculations a large basis of states and complex residual interaction, that needlessly hinders the calculations and limits the area of application of the method only by rather light nuclei [2].

In this connection the approaches based on the use of approximate conservation of the spin-isospin symmetry at an analysis Gamow-Teller excitations [3] and free from the mensioned shortcomings are of interest. However, in ref.[3] the interaction which violates the SU(4) symmetry was chosen uncorrectly. The work [4] seems to be more realistic as compared with ref.[3]. In this work the $2\beta 2\nu$ decay rate of the ^{48}Ca agreeing with experimental data and conclusions of other works is evaluated.

In present work the approach is extended to the case of nuclei having strong nucleon pairing. The calculations of the $2\beta 2\nu$ decay rate was performed for a number of nuclei. There are no any free (varyable) parameters. The all model parameters are taken from independent data. The calculation results are in satisfactory agreement (within the factor 2 - 3) with relevant experimental data.

References

[1] Haxton W.C. Talk presented at XV International Conference on Neutrino Physics and Astrophysics (NEUTRINO'92) Granada, Andalucia, Spain, June 1992. Preprint CERN 40427-21-N92.

[2] Brown B.A., Zhao L. Phys.Rev. C42(1990)1120.

[3] Bernabeu J. et.al Z.Phys. C46(1990)323.

[4] Rumyantsev O.A., Urin M.H. Izv.RAN(ser.fiz.)57(1993)n5,39.

COMPETITION BETWEEN STATISTICAL AND DYNAMICAL PROCESSES IN THE DECAY OF HOT NUCLEI

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The decay properties of hot nuclei are studied in the reactions of ^{136}Xe+^{48}Ti at 18.5A MeV, ^{40}Ar+^{232}Th at 40A MeV and ^{63}Cu+Au at 35 A MeV. In the ^{136}Xe+^{48}Ti reaction, the time scale of the fission process is evaluated for the different mass asymmetries of fission fragments. The extracted time scales to the scission point are 1.0×10^{-20}sec for a symmetric fission and 1.0×10^{-21}sec for a very asymmetric fission. Thus, at the excitation energy above 1 MeV/u, the time scale for the light particle emission becomes shorter than that of the fission process. This may drastically change the decay process of hot heavy nuclei from that predicted by statistical model calculations. The Texas A&M 4π neutron ball has been used to probe the decay of highly excited heavy nuclei produced in the ^{40}Ar and ^{63}Cu induced reactions. For both systems significant cross sections of heavy residues are observed in coincidence with a high neutron multiplicity. Model simulations suggest that these are the evaporation residues from primary compound nuclei with mass A $\sim$ 230 – 260 and excitation energy $E_x \sim$ 700 MeV to 1.5 GeV. It is suggested that, by taking into account the competition between the dynamical and statistical decay processes extracted from the ^{136}Xe+^{48}Ti reaction, the observed residue cross sections can be reproduced.

PREEQUILIBRIUM AND DISSIPATIVE REACTIONS

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We describe nucleon-induced pre-equilibrium reactions as well as heavy ion-induced dissipative reactions in the unified framework of a statistical multistep direct reaction approach. We apply it to inelastic excitation and to transfer to the continuum. In this approach the appropriate strength functions (inelastic or single particle) are calculated microscopically in the QRPA approach, while the reaction amplitudes are determined from multistep DWBA calculations with averaged form factors which are consistent with the strength functions used. The approach is compared to representative examples of continuum reactions (i.e. (n,n′) reactions at low energy and ^{12}C induced reactions at Fermi energies) and is found to give very good descriptions of experimental continuum spectra and angular distributions.

FORMATION OF RESIDUAL NUCLEI FROM HIGLY FISSILE NUCLEI

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The observation of the evaporation residues (ER) of nuclei far from β-stability line allows one to study the different decay channels (xn and αxn) of higly excited compound nuclei for which the fission channel becomes a dominant mode of the de-excitation. In this case the ER production only amounts to a small fraction of the fusion cross section but becomes a higly sensitive probe for the fission dynamics and therefore it may also be used for the analysis of the nuclear dissipation. In this region of neutron deficient nuclei, that are also at the ground state α-emitter, the calculated values of the shell correction for nuclides with the number of neutrons close to the magic number N=126 are practically equal to the calculated values of the liquid drop barrier. This gives one a good opportunity to investigate the influence of the shell effects on the characteristic of the compound-nucleus decay and on the fission channel probability. The xn and αxn channels are analyzed and we study the characteristics of the excitation functions, comparing the results with refined statistical model calculations which account for the time-dependent dynamical effects through the transient time needed to establish a constant flow over the fission barrier. The available experimental data show a steep decrease of the xn-reaction cross sections at the transition from the Ac-Th to U-Np compound nuclei. The αxn-reaction cross-sections also have a sudden decrease but at the transition from U to Pu compound nuclei. A diffused barrier model that accounts for sub-barrier fusion is used. Moreover an appropriate description of the ER production may serve to study the formation of the super-heavy nuclei in heavy-ion reactions.

Refereneces

[1] A. D'Arrigo, G. Giardina, M. Herman, M. Sacchi, A. Taccone, "Evaporation residues by heavy - ion induced reactions", Annual Report LNL - INFN (REP) 81/94, pag. 89

[2] G. Giardina, "Sensitivity of the evaporation residue cross section of highly fissile and neutron deficient nuclei", Proceedings of XII Meeting on Physics of Nuclear Fission, Obninsk , (1993)

[3] A. D'Arrigo, G. Giardina, M. Herman, A.V. Ignatyuk and A. Taccone, "Semiempirical determination of the shell correction temperature and spin dependence by means of nuclear fission", J. Phys. G 20, 365 (1994)

RECENT DEVELOPMENT IN STUDY OF TIME AND ENERGY PROPERTIES OF COMPOUND NUCLEI AT THE RANGE OF UNRESOLVED RESONANCES

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A vast realistical program of research mean values of resonance and time compound - nucleus characteristics is presented basing on

(i.) the general relations (sum rules)

$$\langle \tau^c_{fi}(E,\theta)\rangle = \sum_{js\pi} \langle \tau_{fi}{}^{c(js\pi)}(E)\rangle \langle \sigma_{fi}{}^{c(js\pi)}(E,\theta)\rangle / \langle \sigma_{fi}{}^{c}(E,\theta)\rangle \quad , \quad (1)$$

$$\sum_{fi} \langle \tau_{fi}{}^{c(js\pi)}(E)\rangle \langle \sigma_{fi}{}^{c(js\pi)}(E)\rangle = 2\pi h C^{js\pi} \rho^{js\pi} \quad , \quad (2)$$

$$\sum_{fi} \langle [\tau_{fi}{}^{c(js\pi)}(E)]^2\rangle \langle \sigma_{fi}{}^{c(js\pi)}(E)\rangle =$$

$$= 4\pi h^2 C^{js\pi} \rho^{js\pi} [1/\Gamma^{js\pi} + \pi\rho^{js\pi} M^{js\pi}/N^{js\pi}] \quad (3)$$

(derived in the author's earlier articles -(1) and (3)- and by Lyuboshitz -(2)- in 1977-1993) for nuclear reactions at the range of unresolved resonances.

(ii.) the statistical and optical-statistical approaches to evaluating the mean compound-nucleus differetial, partial differential and partial cross sections $\langle \sigma_{fi}{}^{c}(E,\theta)\rangle$, $\langle \sigma_{fi}{}^{c(js\pi)}(E,\theta)\rangle$ and $\langle \sigma_{fi}{}^{c(js\pi)}(E)\rangle$ supporting on the measured cross sections,

(iii.) the methods of obtaining the mean compound-nucleus total time delay $\langle \tau_{fi}{}^{c}(E,\theta)$ together with the variances $D\tau_{fi}{}^{c} = \langle (\tau_{fi}{}^{c})^2\rangle - \langle \tau_{fi}{}^{c}\rangle^2$, level dencities $\rho^{js\pi}$ and total widths $\Gamma^{js\pi}$ from known and proposed experiments with utilizing the blocking effect, the double collisions and the macroscopic neutron penetration through targets with variable widths and for variable neutron energies.

TIME RESONANCES IN HIGH-ENERGY NUCLEAR REACTIONS

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It is shown that the exponential decrease of the inclusive energy spectra with the final-particle energy in high-energy nuclear reactions, independent of fragments, targets, projectiles and projectile energies, can be explained by new phenomena of time resonances formed by accumulations of strongly overlapped energy resonances. A time resonance does physically correspond to the formation of a high-excited long-living and non-exponentially decaying nuclear clot (nucleon bunch, consisting of a relatively small part of target and projectile nucleons) at the background of a spectator, consisting of the rest of nucleons.

For 200 and more target and progectile nucleons and projectile energies near 1Gev/nucl the widtns of time resonances are between $0.9\cdot10^{-23}$ sec and $4.0\cdot10^{-23}$sec.

The proposed approach is based on selfconsistent quantumtime analysis of nuclear reactions being an alternative way of interpreting the experimental data in comparison with the fireball- model description and also different from the Izumo-Araseki time compound- nucleus approach.

DYNAMICAL EFFECTS IN THE FORMATION CROSS-SECTIONS OF NEUTRON DEFICIENT NUCLEI

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We investigate the sensitivity of statistical model calculations of individual evaporation residue (ER) production on the nuclear shape evolution and viscosity. To this aim we analyze the de-excitation of the ^{217}Ac and ^{200}Po compound nuclei formed at the excitation energies between 34 and 90 MeV. We find a strong dependence of the calculated results on the nuclear dissipation and shape evolution, which make evaporation residues a useful tool for investigating dynamical effects. To this end, we use the refined statistical model which accounts for the time-dependent dynamical effects through the transient time needed to establish a constant flow over the fission barrier. We study the influence of the nuclear shape evolution and viscosity on the individual ER excitation functions and observe an interdependence among the parameters used to describe the dynamical effects. The statistical model used in the present study was described in detail in refs. 1–3. It accounts exactly for the angular momentum and parity coupling, allows for the neutron, proton, and α-particle multiple emission as well as for a fission channel and full γ-cascade in residual nuclei. Particular attention is devoted to the determination of the level densities. These are calculated in the non-adiabatic approach allowing for the rotational and vibrational enhancements. These collective effects are gradually removed above a certain energy. In the case of the rotational enhancement this energy is related to the Coriolis force which couples intrinsic and collective motions. The results of our calculations and the experimental data for the individual ER cross sections are presented. We indicate a new method of estimating the nuclear viscosity and claim that the statistical model interpretation of the ER's does not exclude high values for the viscosity parameter [4].

References

[1] A. D'Arrigo, G. Giardina, M. Herman and A. Taccone, Phys. Rev. C46 (1992) 1437

[2] A. D'Arrigo, G. Giardina, M. Herman, A.V. Ignatyuk and A. Taccone, J. Phys. G20 (1994) 305

[3] A. D'Arrigo, G. Giardina, M. Herman and A. Taccone, *Proceedings of International School-Seminar on Heavy Ion Physics*, Dubna 1993, Vol.2 page 69.

[4] A. D'Arrigo, G. Giardina, M. Herman, M. Sacchi, A. Taccone, "Sensitivity of the evaporation residue production to dynamical effects in higly fissile compound nuclei", to be published in Phys. Lett. B , (1994)

POLARIZATION AND RESCATTERING EFFECTS IN NUCLEAR COLLISIONS WITH EXOTIC NEUTRON-HALO PROJECTILES AT MEDIUM ENERGIES

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The diffraction method developed for describing fragmentation processes of composite stable light ions on spherical and nonspherical atomic nuclei [1-4] is extended to the case of radioactive neutron-reach weakly-bound ion collisions with complex nuclei at intermediate and high energies [5-6]. The spin-orbit interaction of the projectile and the clusters forming it with the target nucleus, as well as the effects of cluster rescattering are taking into account.

The developed formalism is used to calculate in the impulse approximation and with allowance for double scattering the cross sections for elastic scattering and dissociation of ^{11}Li and ^{11}Be ions by ^{12}C nuclei at incident particle energies of 30MeV/A [7] and 33MeV/A [8] respectively, as well as the vector and tensor polarizations of the ^{11}Li and ^{11}Be ions and emitted ^{9}Li and neutron as a function of the parameter characterising the intensity of spin-orbit interaction.

The great sensitivity of the angular dependences of polarizations of the scattered ^{11}Li and ^{11}Be ions and escaping ^{9}Li and neutron to the intensity of spin-orbit interaction of the ^{9}Li and neutron clusters with nuclear target is established.

The strong dependence of polarizations of the final particles on cluster rescattering processes in the elastic scattering and two cluster dissociation of ^{11}Li and ^{11}Be ions on ^{12}C nuclei is also revealed. It is shown that the allowance for cluster rescattering of the incident ^{11}Li and ^{11}Be nuclei leads to the appearence in the polarization angular dependences of sharp maxima and minima that are absent in the impulse approximation.

Thus, the realization of polarization experiments with radioactive beams would be desirable for more precise determination of the parameters connected with the interaction and structure of exotic neutron-rich nuclei.

1.M.V.Evlanov,A.M.Sokolov. Nucl.Phys.A452(1986)77.
2.A.G.Sitenko et.al. Nucl.Phys.A481(1988)1.
3.M.V.Evlanov,A.M.Sokolov.Yad.Fiz.43(1986)1453;44(1986)1191.
4.M.V.Evlanov,A.M.Sokolov,V.K.Tartakovsky.Yad.Fiz.53(1991)953; 53(1991)1559.
5.M.V.Evlanov,A.M.Sokolov.Proc.Intern.Conf."Physics in Ukraine" Kiev, Ukraine, June 1993.P.34.
6 M.V.Evlanov,A.M.Sokolov.Yad.Fiz.56(1993)88.
7.R.Anne et.al. Phys.Lett.B250(1990)19.
8.M.Fukuda et al. Phys.Lett.B268(1991)339.

Semi-microscopic Multidimensional Model of Subbarrier Fusion of Heavy Ions

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A multidimensional [1-4] model for subbarrier fusion of heavy ions which takes into account deformations of ions during fusion process is presented.

A new parametrization of the shapes of colliding nuclei is proposed. In it, the separate shapes can be either oblate or prolate ellipsoid of rotation that go smoothly into fused shape. For this parametrization the energy of heavy ions interaction is calculated and trajectories of their fusion are determined. The rotation energy of the heavy ions is calculated for the finite sizes of the ions. The shell correction energy is take into account at calculation of interaction energy between ions. The adiabatic cranking mass parameters calculated for Saxon-Woods potential and connected with the ions shape deformation is use at calculation of trajectory of minimal action.

In the case of subbarrier fusion within the proposed model, the distance between the centers of mass of the ions at initial and final points of trajectory which describes the motion below the barrier, changes little, while the shape of the ions vary from somewhat oblate to strongly prolate.

The energy dissipation during the collision connected with the energy transfer to another degree of freedom is taken into account.

The competition between fission and particle evaporation after the formation of compound nucleus is taken into account for calculation of evaporation residue cross section.

The calculated fusion and evaporation residue cross sections, mean angular momentum and partial wave cross sections for colliding heavy systems of ions agrees satisfactory with experimental data. The values of mean angular momentum near and below barrier obtained in multidimensional are approximately twice larger then calculated in one-dimensional WKB approach. The partial wave cross section has a large width and long tail.

References

[1] V.Yu. Denisov, Sov. J. Nucl. Phys. **54** (1991) 952.

[2] V.Yu. Denisov and G. Royer, Preprint LPN-Nantes-93-14; J. Phys. G. to be published.

[3] V.Yu. Denisov and G. Royer, Preprint LPN-Nantes-93-05; Submitted to Phys. At. Nucl.

[4] V.Yu. Denisov, S.V. Reshitko and G. Royer, Preprint LPN-Nantes-94; In: Proc. Int. Workshop on Heavy Ion Fusion, Padova, May 1994, World Sci. Publ. Co.

PREEQUILIBRIUM DECAY IN THE EXCITON MODEL FOR NUCLEAR POTENTIAL WITH A FINITE DEPTH

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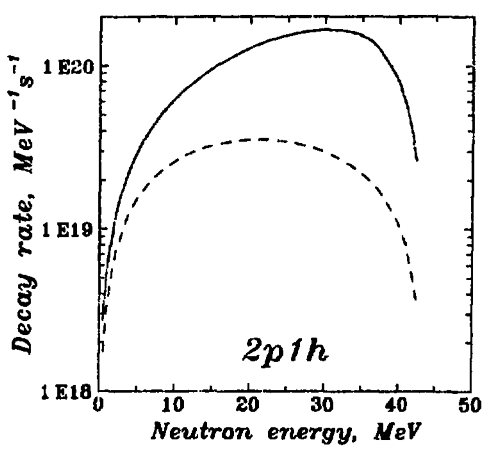
For a realistic finite depth potential well the value of single-particle level density $g(\varepsilon)$ decreases with the single-particle energy ε in continuum region [1]. This leads to the reduction in the particle-hole level density $\omega_{ph}(E)$ when the high value of excitation energy is shared between a small number of excitons [2]. To clarify how the finitness of the potential depth influences the preequilibrium decay rates, we calculate the emission rates for neutron

$$W_{ph}(\epsilon_n) = \frac{1}{2\pi\hbar} \frac{\omega_{p-1\,h}(U)}{\omega_{ph}(E)} \sum_{\ell} (2\ell+1) T_\ell(\epsilon_n) \ .$$

Here ϵ_n is the energy of emitted neutron, $\omega_{p-1\,h}(U)$ is the particle-hole level density for residual nucleus, T_ℓ stands for the neutron transmission coefficients. Symbols p and h denote the numbers of excited particles and holes. Excitation energy U of residual nucleus is related to that of initial nucleus through the energy conservation law. Calculations for ^{208}Pb at excitation energy $E = 50$ Mev have been performed . Particle-hole level densities were determined using $g(\varepsilon)$ for trapezoidal potential. The parametrization of this potential has been taken from [1]. Figure shows that the effect of finite depth of potential well is in evidence for $2p1h$ configuration.



Partial dacay rates for preequilibrium neutron emission from ^{208}Pb. *Dashed line* represents the calculation for infinite trapezoidal potential. *Solid line* corresponds to trapezoidal potential without free-gas spectrum contribution. Particle-hole configuration is inserted

References

[1] S. Shlomo, Nucl. Phys. **A539** (1992) 17

[2] S. Shlomo, Ye.A. Bogila, V.M. Kolomietz and A.I. Sanzhur, Phys. Lett. **B** (1994) to be published

DECAY TIME CHARACTERISTICS OF HEAVY EXCITED NUCLEI

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Analysis of the time characteristics of the decay of heavy fissionable excited nuclei in the framework of the double-humped fission barrier model and statistical theory of nuclear reaction revealed that the quasistationary states in the second potential well have influence upon decay low and yield of decay products [1]. The present contribution is a review of the series of the experimental and theoretical investigations of the decay time characteristics and statistical, dynamical and statical properties of the strongly deformed states in the second potential well of the excited heavy nuclei. The mean decay times in the fission channel of the Pa, U, Np and Pu isotopes excited to a few MeV above the fission barrier have been measured by the blocking technique [2, 3]. The fission lifetime values for the investigated nuclei are in the range from 10^{-15} sec to 10^{-17} sec at excitation energies from 6 MeV to 12 MeV respectively. The lifetimes of the excited states in the second potential well - τ_2 were extracted from the experimental data. It was demonstrated that τ_2 is the considerable part of the total decay time in the fission channel. The observed values τ_2 contain information on the level density in the second potential well and parameters of the fission barriers. It was shown, that the level densities in the second potential well are considerable more than the level densities in the first well at the same internal excitation energy. The nature of this distinction is a consequence of violation of axial and reflection symmetry of the nuclear shape in the excited states of the second potential well. The decay law of the nuclei with two classes of excited states is discussed.

References

[1] O.A.Yuminov Proc. 14th All-Union Meeting on The Interaction of Charged Particles with Single Crystals, Izd.MGU, 1985, p.68

[2] V.O.Kordyukevich et al., Nucl.Phys., **A492** (1989) 447

[3] S.Yu.Platonov, O.V.Fotina, O.A.Yuminov, Nucl.Phys., **A503** (1989) 461

THE INTERFERENCE PHENOMENON IN THE EMISSION OF BREMSSTRAHLUNG QUANTA ACCOMPANYING THE NUCLEAR PROCESSES

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The dynamics of formation and decay of the excited nuclear states is an acute problem in the modern nuclear physics. The investigations of the interplay between atomic and nuclear processes give us a new information about the different mechanisms of nuclear reactions. The method based on the time-interference effects of bremsstrahlung quanta accompanying the nuclear interactions is enable to measure the lifetimes of excited states of compound nuclei in the limits from 10^{-22} to 10^{-19} s.

The usefulness of this method is demonstrated for the cases of $^{12}C(p,p\gamma)$ and $^{16}O(p,p\gamma)$ reactions in the regions of overlapping and isolated resonances. It is shown that the lifetime of nuclear excited state near the isolated resonance level is depended from the resonance parameters and correlations between the direct reaction amplitude and amplitude of compound nucleus formation. If the time-reversibility violation in nuclear reaction is connected with complex nature of the reduced width amplitudes, therefore there is the possibility to observe the time-reversibility violation effects by means of bremsstrahlung method. We show the possibility of this method for the case of $^{27}Al(p,p\gamma)$ reaction.

One more example of the space-interference effects is the high energy bremsstrahlung emission in the fission process. Our experimental data and theoretical calculations to the case of spontaneous fission of ^{252}Cf-nucleus show that the shape of the energy spectrum of photons is sensitive to the dynamics of fission.

EFFECTS REVEALED IN THE BREMSSTRAHLUNG EMISSION AND INFLUENCE OF THE COMPOUND-NUCLEUS MOTION ON THE INTERFERENCE PROCESSES IN CROSS-SECTIONS

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Detailed researchs of proton-nucleus collisions accompained by the bremsstrahlung emission established that delay-advance effects are connected with the interference between one or two resonances and the non-resonant background [1, 2]. The ^{16}O (p, p) and ^{12}C (p, p) reactions at beam energies included in the 1.5 – 2.7 MeV range are considered when an isolated resonance (3.105 MeV, $1/2^-$ of the ^{17}F compound nucleus) and two superimposed resonances states (3.511 MeV, $3/2^-$ and 3.547 MeV, $5/2^+$ of the ^{13}N compound nucleus) are involved, respectively. Here we present the further development of the theory of delay-advance effects taking into account the motion of the compound nucleus before its decay in the laboratory system and also spins and spin-orbital splitting.

Moreover a self-consistent space-time analysis (made in the laboratory system) of the interference between non-resonant (prompt) and resonant (delayed) processes in nuclear reactions with two-particle channels, leads to a generalization of the expressions obtained (in the center - mass system) in the framework of an almost stationary formalism. The role of a new phase parameter φ, which describes the space-time shifts between the sources of the final-particle emission caused by the motion in the laboratory system of the decaying compound-nucleus, is analysed. We find that in many realistic cases (when $\varphi \sim 1$) the effect related to this motion produces noticeable changes in the cross sections [3].

References

[1] A. D'Arrigo, N.L. Doroshko, N.V. Eremin, G. Giardina, B.V. Govorov, V.S. Olkhovsky and A. Taccone, Nucl. Phys. A549, (1992) 375

[2] A. D'Arrigo N.L. Doroshko, N.V. Eremin, G. Fazio, G. Giardina, B.V. Govorov, V.S. Olkhovsky and A. Taccone, Nucl. Phys. A564, (1993) 217

[3] Eremin, G. Giardina, V.S. Olkhovsky, S.A. Omelechenko, "Temporal description of interference phenomena in nuclear reactions with two-particle channels", submitted to Mod. Phys. Lett. , (1994)

LEVEL DENSITY OF HOT NUCLEI

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Recently, there has been a renewed interest on the temperature dependence of the nuclear level density parameter. This interest is stimulated by new experimental data. An agreement with the experimental data was obtained by taking into account the effects of finite size of nucleus.

We calculate the smoothed single-particle level density based on semiclassical calculations of bound and unbound states in a Woods-Saxon potential well using the Strutinsky smoothing procedure. The accuracy of this approach is enough to obtain a reasonable agreement with the experimental data.

We also tried to derive the semiclassical expression for shell corrections with inclusion of continuum states based on our earlier paper /1/ and some results of paper by M. Gutzwiller /2/.

1. Strutinsky V.M., Magner A.G., Ofengenden S.R., Dossing T. Z.Phys.A. 1977. V.283. P.269-285.
2. Gutzwiller M.C. Chaos. 1993. V.3. N.4. P.591-599.

ROTATIONAL BANDS OF DEFORMED NUCLEI AND SL(3,IR) SYMMETRY

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The work is dedicated to the application of the noncompact group theory in nuclear spectroscopy. By the method of induced representations the principal series of representations of SL(3,IR) group is constructed. The results obtained are applied to the description of E2-transition probabilities in even - even deformed nuclei (*with mass number* $150 < A < 194$).

V.STRUTINSKY AT THE KURCHATOV INSTITUTE DURING THE CREATION OF THE SHELL METHOD

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V.Strutinsky began his scientific activities at Kurchatov's Institute after graduating the Kharkov University at 1953.

Discovery of nonspherical form of heavy nuclei attracted his attention and influenced his further scientific interests. He performed the work concerning the angular correlation during alpha decay and developed the theory of angular anysotropy of fission fragments. Afterwards the fundamental works were performed on investigating the process of fission of heavy nuclei. They based on Nils Bors's drop model: equilibrium nucleus form, stability of nucleus form including on condition of changing the surface tension. These works and reports at Conference "Physics and Chemistry in Fission" (1964) "Effect nucleon pairing in nuclear fission" and "On fission of deformed nucleon" have led Strutinsky to publishing his fundamental work "Shell effects in energy of the nucleus" performed at Kurchatov's Institute (Preprint Kurchatov's Institute, IAE-879, Moscow, 1965). Afterwards this work was printed in "Nuclear Physics" at 1967. It became Strutinsky's most known publication being cited widely.

At 1967 V.Strutinsky was directed by Kurchatov' Institute to Denmark, to N. Bohr's Institute for developing the shell corrected method to calculate energy of heavy nuclei deformed. This method was elaborated by Strutinsky. Successful activities at Bohrs's Institute was finishes at 1970. Then he leaves to Kiev for work at Institute of Nuclear Investigations of Ukrainian Academy of Science.

The development of shell corrected method led him to discovery of fission through two hump barrier. It stimulated the vigor development of experimental works at many laboratories over all the world. Their aim was to detect and to investigate effects of the second (and third one) potential well in fission process.

After Bohr and Wheeler works the new stage of understanding the fission process is connected with V.Strutinsky activities. With time the Science History will take him well-deserved place. Unfortunately, by my opinion, the Strutinsky's contribution to Fission Physics was not understood by many scientists of the former Soviet Union.

ON ACCELERATION OF POLARIZED IONS UP TO INTERMEDIATE ENERGY AT NEW FACILITY

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Main topics of polarization phenomena investigation at meddle and intermediate energies and contemporary methods of production and acceleration of various polarized ions are described. Problems of a polarized ions acceleration at the isochronous cyclotron U-240 and storage ring for A=1–40 ions are studied: i) depolarization resonances and means to overcome their action; ii) optimal conditions to conserve maximal beam polarization after passing of a transport beam line; iii) possibilities to accumulate polarized radioactive ions in the storage ring.

Perspectives of shell structure investigation with polarized beams are considered.

The Role of Statistical Fluctuations in Heavy Ions Collisions and Fission of Compound Nuclei[1]

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Abstract

Statistical fluctuations play an important role in nucleus-nucleus collisions and in the decay of hot nuclei. Nevertheless we have impression that the role of the fluctuations is overestimated in some theoretical models. The spin distribution of a fused nucleus is not only governed by the reaction dynamics and the fluctuating force but also by the entrance channel effects. We intend to estimate the effect of the deformation of colliding nuclei on the spin distribution of the fused system. Also the outcome of the fission process accompanying by light particles emission is strongly correlated with the initial spin distribution and the excitation energy of the compound system.

In order to work out the fusion cross sections and their dependence on angular momentum we have developed a simple model based on transport concepts. The multidimensional Langevin equation similar as in Ref. [1] is used for description of heavy ions collisions. The liquid drop potential energy, the hydrodynamical inertia and the one body dissipation with a standard set of parameters taken from [2] are used. We have also used the standard Einstein relation in order to estimate the diffusion tensor.

We have reproduced relatively well the partial fusion cross section as a function of the angular momentum. Contrary to our previous estimates made without taking effects of ion deformations into account [3], we have obtained a better agreement also for higher angular momenta. *There is no more need to increase the magnitude of the diffusion tensor or the surface friction.* Additionally we have found that even with the simple model [2,4] without fluctuating force, the taking into account the influence of the ion deformations on the height of the Coulomb barrier allows to reproduce the experimental value of the average angular momentum of the fused system and its variance.

References

1. P. Fröbrich and S.Y. Xu, Nucl. Phys. A477 (1988) 143
   P. Fröbrich, Nucl. Phys. A545 (1992) 87c
2. H. Feldmeier, Rep. Prog. Phys. 50 (1987) 915
3. W. Przystupa and K. Pomorski, Nucl. Phys. A572 (1994) 153
4. J. Błocki, H. Feldmeier and W.J. Swiatecki, Nucl.Phys. A459 (1986) 145