PN–II–ID–PCE–2008–2

FUNDING APLICATION FOR EXPLORATORY RESEARCH PROJECTS

1. Personal data of the project manager:

1.1. Surname:	**RADUTA**
1.2. First name:	**CRISTIAN MIRCEA**
1.3. Year of birth:	1972
1.4. Didactic and/or scientific title:	SeniorResearcherIII (Select)
1.5. PhD since the year:	2005
1.6 Doctorate coordinator:	NO (Select)
1.7 Number of candidates for doctor's degree:	0

2. Host institution:

2.1. The name of the institution:	INSTITUTE OF PHYSICS AND NUCLEAR ENGINEERING-HORIA HULUBEI *[fill in the institution name]*
2.2 Faculty/ Department:	THEORETICAL PHYSICS
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3. Title of the project: (Max. 200 characters)

ADVANCED STUDIES ON COLLECTIVE MOTION, PHASE TRANSITIONS AND FUSION DYNAMICS IN COMPLEX NUCLEAR SYSTEMS.

4. Key words (max. 5 terms):

1	SYMMETRIES
2	PHASE TRANSITIONS
3	COLLECTIVE MOTION
4	COHERENT STATES
5	NUCLEAR FUSION

5. Project duration (3 years): **3**

6. Project summary: **(Max. 2000 characters)**

THE PROJECT PROPOSES SOLUTIONS TO SEVERAL TOP SUBJECTS OF NUCLEAR STRUCTURE AND FUSION. SINCE THE ANHARMONIC BOSON MODELS ARE TEDIUOS TO BE HANDLED MANY GROUPS LOOK FOR SOLVABLE MODELS DESCRIBING THE NUCLEAR DEFORMATIONS. THE ENTHUSIASM GREW VERY MUCH SINCE ONE HAS BEEN SUGGESTED THAT THE CRITICAL VALUES OF THE ORDER PARAMETER FOR A PHASE TRANSITION CORRESPONDS TO A SPECIFIC SYMMETRY. THESE ARE E(5) WHEN ONE GOES FROM SU(5) TO O(6) AND X(5) FOR THE TRANSITION SU(5) TO SU(3). SOLVABLE MODELS STAY CLOSE TO THESE SYMMETRIES AND IMPROVE THE AGREEMENT WITH THE EXPERIMENTAL DATA. THE EXISTENT THEORIES HAVE SEVERAL STRONG DRAWBACS WHICH ARE TO BE REMOVED. WE ATTEMPT TO DEFINE SOLVABLE MODELS WHICH PRESERVE THE PROPERTIES SUGGESTED BY THE STRUCTURE OF THE INITIAL HAMILTONIAN: THE FUNCTION ARE TO BE PERIODIC OF GAMMA, THE HAMILTONIAN SHOULD BE HERMITIAN, THE FUNCTIONS DESCRIBING THE BETA DEFORMATIONS MUST BE ORTHOGONAL. TO TAKLE WITH THESE ISSUES WE USE VARIOUS MATHEMATICAL TOOLS LIKE DYNAMIC SYMMETRIES , DIFFERENTIAL EQUATIONS AND ASSOCIATED SYMMETRIES, ALGEBRA CONTRACTIONS, COHERENT STATES FOR THE DYNAMIC SYMMETRY GROUPS, SEMICLASICAL DESCRIPRION, GEOMETRIC QUANTIZATION.THE FINAL AIM IS TO OBTAIN NOT ONLY A WELL DEFINED, SIMPLE AND LOGICAL MATHEMATICAL MODEL BUT ALSO A REALISTIC DESCRIPTION OF THE EXPERIMENTAL DATA CONCERNING EXCITATION ENERGIES AND TRANSITION PROBABILITIES. THE NUCLEAR STRUCTURE DESCRIPTION OF THE MEAN FIELD IS ALSO USED FOR INTERPRETING THE DYNAMIC FEATURES OF THE NUCLEAR FUSION WITH EXOTIC NUCLEI.THE FUSION PROCESS FOR EXOTIC NUCLEI IS CONSIDERED AND NEW RESULTS FOR PRE-EQUILIBRIUM DIPOLAR MODEL IN THE ENTRANCE CHANNEL ARE EXPECTED. THE YIELD OF COLLECTIVE PHOTONS WILL BE CALCULATED WITHIN A CLASSICAL BREHMSSTRAHLUNG FORMALISM. RESULTS SENSITIVITY TO VARIOUS DENSITY DEPENDENCE OF THE SYMMETRY ENERGY TERM OF THE MEAN FIELD WILL BE STUDIED. THE PROJECT USES EFFICIENTLY THE TEAM SKIL IN NUCLEAR STRUCTURE AND REACTIONS, AND MATHEMATICAL METHODS.

7. Project presentation:

[Please fill in max. 10 pages in ANNEX 1]

8. Project management:

[Please fill In ANNEX 2]

9. Budget (eligible cost)*:

CRT. NO.	NAME OF THE BUDGET CATEGORY	VALUE 2008***	VALUE 2009***	VALUE 2010***	VALUE 2011***	TOTAL VALUE

		(euro)	(euro)	(euro)	(euro)	(euro)
1.	**STAFF EXPENSES**** - ***max. 60%*** including state tax and other contribution	24590	49180	49180	40984	**163934**
2.	**INDIRECT EXPENSES** *(overheads)*	8197	13661	13611	11403	**46922**
3.	**MOBILITIES** *(participation in prestigious scientificevents / documentation; research stages in contry or abroad)*	6010	16394	16394	10455	**49253**
4.	**LOGISTIC COSTS** for carrying on the project *(research infrastructure, costs for materials, dissemination etc.)*	2186	2732	2732	5465	**13115**
	TOTAL	**40983**	**81967**	**81967**	**68307**	**273224**

* Structure of budget must be in accordance with the HG 1579/2002

** Staff expanses must be calculated in acordance with the size of research team and HG 475/2007

*** 2008 – 3 month, 2009 – 12 month; 2010 – 12 month; 2011 – 9 month.

10. Project manager is full time employed in the host institution

(Select)

YES

IT IS CERTIFIED HEREBY THE LEGALITY AND CORRECTNESS OF THE DATA INCLUDED IN THE PRESENT FINANCING REQUEST

DATE:

RECTOR/MANAGER,
Surname, first name:**Dr. Nicolae Zamfir**
Signature:
Seal

ACCOUNTING MANAGER/CHIEF ACCOUNTANT
Surname, first name:Ec. Alexandru Popescu
Signature:

PROJECT MANAGER,
Surname, first name:Dr. Cristian Mircea Raduta
Signature:

7. Project presentation: (Max. 10 pages)

7.1. IMPORTANCE AND RELEVANCE OF THE SCIENTIFIC CONTENT

Phase transitions of finite nucleon systems represents a top subject in nuclear physics. This phenomenon has been studied both, microscopically and phenomenologically. Here are few examples: a) pairing the alike nucleons provided a realistic description of the superconductor properties of even-even nuclei. The ground state for a system with pairing correlations included is lower in energy than the ground state of the same system but without pairing interaction. The ground state of a pairing correlated system placed in a single j orbit is a coherent state for the quasi-spin SU(2) group. b) The ground state of a many body nucleon system interacting among themselves through a long range quadrupole-quadrupole force is also a coherent state. Moreover, the state depends on the interaction strength X. Within a random phase approximation (RPA) approach this is a vacuum state for the quadrupole RPA phonons. If the mean field which describes the single particle motion exhibits spherical symmetry then the quadrupole phonons define states with spherical symmetries. If we progresively increase X, the energy of the collective state, the first RPA state, is decreasing and finally vanishing. The state corresponding to the vanishing energy is spurious. The vanishing of the first RPA energy is a signal that the single particle state with spherical symmetry is inadequate. One says that for that critical value of X, a phase transition from spherical to deformed mean field took place. It is worth mentioning that the vanishing energy, defining the Goldstone mode, represents a new symmetry. Indeed, the phonon operator commutes with the Hamiltonian and, therefore, generates a symmetry. It is obvious now that at the critical X, where the transition between two nuclear phases, spherical and deformed shapes, a new symmetry shows up. As we shall see later on this idea will be met again in the context of the phenomenological models. c) Until recently, the proton-neutron (pn) pairing interaction has been ignored. The invoked reason was that the Fermi levels of the two systems are energetically far away from each other. However, this is not true whenever Z=N, which may happen both for stable and unstable nuclei. The nucleons of similar isotopic charge may form pairs with T=1, while protons and neutrons might be paired either to T=1 or to T=0. Therefore, if the pn pairing interaction is missing then the ground state comprises only the T=1 pairs pp and nn.If the pn pairing interaction is switched on it is likely that a ground state where the T=0 pn pairs prevail over the T=1 pn pairs, shows up (A. A. Raduta, V. Baran et al, Nucl. Phys. A 675 (2000) 581). This nuclear phase is not yet identified althouth there are some attempts that the spectrum of 76Fe be interpreted as beeing caused by the intersection of a collective yrast band and a 2qp band starting with 10+. The 2qp states are determined by breaking a T=0 pn pair. Let us now see how the phase transitions are possible within phenomenological models.d) Within a collective anharmonic boson model, the GG(Greiner-Gneuss) model for example, depending on the structure coefficients the equipotential surface energy may have various types of minima: spherical, deformed-prolate, deformed-oblate, triaxial deformed, etc. For each type of minima there exist specific properties for energies as well as for transition probabilities between energy levels. For this reason one customarily says that the static values of the nuclear collective coordinates determine a certain nuclear phase. Thes nuclear shapes or phases manifest themselves through a certain energy ordering of the excited bands beta and gamma. If the first gamma state is higher in energy than the first beta band state, the system is gamma stable. If the opposite ordering takes place the system is gamma unstable. There exits a distinct phase when the states from beta and gamma bands carrying the same angular momentum, are quasi-degenerate. Such a situation might be described by an axially symmetric rotor. A serios drawback of the GG model is the large number of parameters. A much smaller number of parameters is used by the coherent state model (CSM) (A.A.Raduta et al, Nucl. Phys. 381 (1982) 253). This model describes the three mentioned rotational bands as angular momentum projected states from three orthogonal deformed states: a coherent state and two polynomial excitations of it. The model capacity to realistically describe the nuclei from various nuclear phases has been proved in Ref. A. A. Raduta et. al, Jour. Phys. G 31 (2005) 873. Each nuclear phase corresponds to a certain symmetry defined by the collective coordinates. To give examples, the nuclear phases mentioned above correspond to the symmetries SU(5), O(6), and SU(3). Casten placed all nuclei on the sides of a triangle bearing in corners the symmetries just mentioned. It has been shown that on one side (SU(5)-O(6)) a first kind phase transition take place while on another one (SU(5)-SU(3)) a second kind of phase transition shows up. Recently, Iachello showed that the critical point of the SU(5) to O(6) transition defines a new symmetry called E(5). Later on the same author defines the symmetry X(5) which corresponds to the SU(5) to O(6) transition. The irreducible representations for the group E(5) are Bessel functions of half integer index. The symmetry X(5) is defined by a harmonic approximation for the gamma deformation and the irreducible representations are the Laguerre polynomials. These two contributions open the field of solvable models for the nuclear deformations beta and gamma. It is amasing that the contributors forgot that in fact thirty years ago two members of this project gave a fully analytical solution for the harmonic liquid drop wave functions(A. Gheorghe, A. A.

Raduta et al., Nucl. Phys. A256 (1978) 228, and A.A.Raduta, A. C. Gheorghe et al. Nucl. Phys. A311 (1978) 118). They ignore not only the history but also three fundamental feature: The Bessel functions for distinct states have different arguments and therefore are not orthogonal; the functions which describe the variable gamma are not periodic as the initial Hamiltonian requires; the final Hamiltonian is not Hermitian with respect to the integral measure for gamma. Remedies for these drawbacks represent the major objectives of this project. Recently two members of the team treated, bringing many criticisms, both the symmetry E(5) (A.A.Raduta, A. Gheorghe et al., 31(2005) 337) and X(5) (A. C**.** Gheorghe, A. A. Raduta and A. Faessler, Phys. Lett. B 648 (2007) 171-175).e) Another nuclear phase is met in nuclei exhibiting static nuclear deformation. For such systems two symmetries are broken: rotation symmetry and space reflexion symmetry. One expects that these two spontaneously broken symmetries to be associated with new properties of the nuclear system.

Coherent states have been introduced by Schroedinger already in 1926, but received the deserved attention only after Glauber noticed that they are useful in optic. There are several definitions of the coherent states, some of them being equivalent to each other. *A coherent state is a wave function associated to a system for which the uncertainty relations for the conjugate variables of coordinate and momentum attain their minimum.* The coherent state in the Perelemov sense is a group orbit applied to a special Hilbert state. Coherent states have many properties which proved to be useful in physics. From these we depict the supercompletness which implies two consequences of a major importance: 1)Expanding an arbitrary function in the superbasis of the coherent states, the expansion coefficients are not uniques. 2) Expanding a coherent state in an orthonormal basis then no exapnsion coefficient is equal to zero. The property 2) allowed us to project out an orthonormal basis for the group SU(5) from a coherent state defined with the components of a quadrupole boson. The coherent states in the sense of Perelemov for the Weyl group coincide with those of Glauber type for the harmonic oscillator. Another cas of coincidence is not yet known. The coherent states are quite often used as trial functions by the time dependent variational formalisms. The question which arises is why the coherent states? The reasons is that the classical equations lead after quantization to a spectrum which is very close or identical to the one characterizing the quantum mechanical starting Hamiltonian. Our group has used this property to describe semiclassically many body systems **(**A.A.Raduta,A.Gheorghe, et al., Nucl. Phys. A 427 (1984)1 and a triaxial rigid rotor **(**A.A.Raduta, C.M.Raduta, Phys.Rev.C, 76, 064309,(2007)). In this context we mention that dequantizing the system via a variational time dependent principle, describing classically the motion and then quantizing the trajectories might provide important simplifications in the description of the system. Coherent states for two independent variables have been recently used as mathematical tools for teleporting and entanglement of information. Our grup will continue the use of coherent states to quantize the classical systems as well as for a quantitative description of nuclear systems.

Nuclear fusion dynamics. In the recent years important research laboratories developed experimental facilities related to the production of exotic and radioactive beams. These developments opened new perspective in the investigation of nuclear structure, reaction mechanisms and processes of astrophysical interest. A key question is the knowledge of the equation of state (EOS) of asymmetric nuclear matter away from normal conditions. Since during the reaction dynamics with exotic nuclei we can probe highly asymmetric nuclear matter in strongly compressed as well as dilute phases, a clever analysis allows extracting relevant information about EOS, which, in turn, can be related to the features of effective interactions in nuclear medium. The isospin dynamics as well as the effects of symmetry energy in various reaction mechanisms were intensively studied during the last five years. The investigation of the isospin effects in fusion and deep-inelastic reactions with exotic nuclei, as obtained in the framework of microscopic transport models of Boltzmann-Nordheim-Vlasov type, represents an important component is this recent world-wide effort. During the early stages of heavy ions collisions large amplitude collective motions can be excited. Tracing information from their decay provides the opportunity to learn about the features of the fermionic systems in such extreme, far from equilibrium, conditions. If the colliding nuclei have different N/Z ratio the charge equilibration process take place and several experimental and theoretical investigations have suggested that the related neutron-proton collective motion has the features of a giant dipole resonance (GDR) mode (V.Baran et al. Nucl.Phys.A 1996).Recent theoretical and experimental studies were focused on the properties of this mode in collision between normal nuclei. The first microscopic approach of preequilibrium dipole radiation and a realistic estimate of gamma emission was published by us in 2001 (V.Baran, D.M. Brink, M. Colonna and M. Di Toro, *Physical Review Letters* 87 182501, V. Baran et al. *Nucl. Phys. A* 679, 373) and stimulated several experimental investigations which confirmed our predictions, see Pierroutsakou D et al. *Eur. Phys. J A* 16 423 (2003) , Pierroutsakou D, et al. *Phys. Rev. C* 71 054605 (2005), B. Martin et al. *American Institute of Physics Conf. Proc.* **831,** 505 (2006).Of great interest, as **recent Scientific Objectives of the important European project SPIRAL 2 illustrate (see web page** www.ganil.fr/research/developments/**spiral2)** is to extend these investigations to systems which include exotic nuclei, having large N/Z ratios. Among the challenges of the modern nuclear physics this project pointed out the structure of exotic nuclei, the dynamics and

thermodynamics of charge asymmetric nuclear matter, understanding the origin of the elements, fundamental interactions beyond the standard model. Our proposal is fitting perfectly on these priorities.

7.2. Project objectives

Phase transitions. 1**)** *New collective multipolare models with radial symmetry for an analytical description of nuclear phase transitions*. A familly of collective Hamiltonians separables in radial and angular variables will be considered. This familly will involve the Bohr-Mottelson Hamiltonian [1]and the Hamiltonian yielding the E(5) symmetry[2].Using the group of dynamic symmetries for the Schroedinger equation the Hamiltonians in the radial variables admitting solvable and partialy solvable potentials will be classified. The spectra and the corresponding wave functions for such Hamiltonians will be derived. Special symbolic codes will be elaborated to construct explicitly the octupole basis for the the liquid drop Hamiltonian. Using potentials which do not depend on angles and then using the results of Ref[3] for the basis of multipole oscillator we shall calculate explicitly the spectra and transition probabilities. The theoretical results will be compared with the experimental data. Another class of dynamical symmetry will be introduced to describe the phase transitions in octupole deformed even -even and odd nuclei. Symmetries algebras and dynamic supersymmetries will be achieved in terms of differential operators. 2)*New solvable collective models for transitional nuclei described by differential equations which are periodic in deformation variables.* We shall introduce a familly of quadrupole Hamiltonians by means of differential operators periodic in angles. In particular, a special attention will be paid to the differential equations in the gamma variable satisfied by the Mathieu functions and the generalized spheroidal functions, respectively. Contrary to the model X(5) [4], these equations preserve the periodicity for gamma and the Hamiltonian hermiticity. First models of this type were introduced in [5]. Analytical as well as numerical methods for testing whether the gamma small approximation used by the X(5) model is also asymptotically valid. The results concerning the excitation energies and transition probabilities will be compared with the corresponding experimental data. The considered models will be characterized by the symmetry groups of the associated differential equations. In particular an answer to the open problem regarding the symmetry group for the X(5) model will be given.3)The contractions of the dynamic groups in the region of the phase transition critical points. The Lie group contraction has been introduced by Inonu and Wigner [6] as rigourous mathematical method to obtain a nonrelativistic mechanics as a limit of the relativistic mechanics. More precisely, the goal was to obtain the homogenous Galilei group by the contraction of the orthocron Lorentz group. Thus the euclidian group E(2) is obtained by contraction from the groups SO(1,2) and SO(3). Dynamic symmetries are realized by Lie goups and algebras, quantum goups and algebras, supersymmetries, etc. It is essential to obtain the limiting symmetries performing the contractions through singular transformations. The nuclear phase transitions will be characterized by dynamic groups contractions. The model E(2n+1) describes the solution of a multipolar Bohr Hamiltonian for a square well potential in 2n+1 dimension. The quadrupole and octupole cases are obtained for n=2 and n=3, respectively. The contraction of the euclidian group E(2n+1) will be performed by the contraction of both the orthogonal group SO(2n+2) and the pseudo-orthogonal SO(1,2n+1). The E(2n+1) contraction will be characterized by explicite asymptotic formulae where the Bessel functions, associated to euclidian groups, are obtained from the Laguerre functions associated to the orthogonal groups. The first asymptotic formula for E(5) has been obtained [7].**References**: [1] A. Bohr, Mat. Fys. Medd. Dan. Vid. Selsk. 26, no.14 (1952); A. Bohr and B. Mottelson, Mat. Fys. Medd. Dan. Vid. Selsk. 27, no. 16 (1953)[2] F. Iachello, Phys. Rev. Lett. 85, 3580 (2000)[3] A. C. Gheorghe, A. A. Raduta, J. Phys. A: Math. Gen. 37, 10951 (2004)[4] F. Iachello, Phys. Rev. Lett. 87, 052502 (2001).[5] A. C. Gheorghe, A. A. Raduta , A. Faessler , Phys. Lett. B 648 (2-3), 171 (2007)[6] E. Inonu, E. P. Wigner, Proc. Nat. Acad. Sci. USA 39, 510 (1953)[7] A. A. Raduta, A. C. Gheorghe, J. Phys. G: Nucl. Part. Phys. 31, 337 (2005).

Coherent states. 1) In the framework of geometric quantization we shall construct dynamic symmetry and supersymmetry algebras by means of differential operators on coherent state orbits. We will obtain explicit boson realizations of these algebras for collective Hamiltonian. The family of the considered dynamical groups is large and contains the holomorphic discrete series of semisimple Lie groups and the irreducible unitary representations of the Heisenberg groups and compact groups. We will present symbolic calculus programs for bosonic realizations. In the case of compact groups, we will obtain semiclassical spectra considering trial functions determined by the uniparametric subgroups of the complexified dynamical Lie algebra. We will refine the Maslov corrections. 2) In the framework of coherent states, we will obtain the semiclassical spectra and quantum correction series for the families of multipole collective models, rotational models, and generalized Lipkin models. We will compare the results with the corresponding quantum asymptotic spectra. We will study the classical and thermodynamic limits of the considered models. 3) We will explicitly obtain the coherent states for the solvable radial multipole potentials. Moreover, we will construct the coherent states for the multipole group chain of the Bohr-Mottelson collective model in the holomorphic, boson and vector realizations. Moreover, we will construct the

coherent states for the Euclidean multipole model (an open problem of Iachello for E(5)).
Nuclear fusion dynamics. The important goal is to explore the dynamical role of the symmetry term of the mean-field as well as the effects of neutron skin on fusion reaction between exotic nuclei. We will focus on excitation of pre-equilibrium dipole mode and associated gamma yield of importance from theoretical as well as from experimental point of view. We will inquire on the dependence of these phenomena on beam energy as well and on the N/Z difference in entrance channel. Of a peculiar interest is the presence of Pigmy Dipole mode, related to the oscillations of weakly bounded neutron against the isospin symmetric core. In medium mass nuclei, including nickel and thin isotopes, various models predict different amounts of collectivity for this soft modes and it is under debate if this motion is collective at all. Since one of the major advantages of the proposed theoretical framework is the self-consistent description of the interplay between various degrees of freedom, we intend to apply our model to such low-lying dipole mode. A comparison with the predictions of other approaches of mean field type and experimental results can add clarifications on the collective nature of this mode.The correlations between estimated gamma yields and symmetry energy term will provide significant hints on the features of the later when a comparison with experimental data is performed. To achieve these goals we will employ a microscopic transport model of Boltzmann-Nordheim -Vlasov type to study the dissipative reactions with exotic nuclei. This approach offers the opportunity to follow in a self-consistent way the interplay between the fusion dynamics and collective modes. We shall focus on colliding systems like $^{132}Sn+^{58}Ni$ at various beam energies between 5 MeV/A and 20 MeV/A. Some other systems studied in various recent experiments will also be considered. The excitation of collective modes in the entrance channel of fusion dynamics will be investigated in great detail. We shall follow the establishment of the local equilibrium, the time dependence of monopole and quadrupole moment, the particle pre-equilibrium emission. From the time dependence of the dipole moment along symmetry axis we extract the collective photon yield resulting from such pre-equilibrium giant dipole resonances. The dependence of these features on beam energy and symmetry energy term provide information which by comparison with experimental data may offer complementary insights concerning the density dependence of symmetry energy term in equation of state of nuclear matter.

7.3. Methodology of the research

The proposed researches imply several stages necessary for any fundamental or theoretical investigation:1) Fixing a working program as well as the way in which each participant takes part in the project. 2) Comparing the analytical results obtained by experienced researchers. 3) Encouraging the PhD student to perfom himself those analytical calculations, which are not beyond his training level. 4) Writing the codes necessary for numerical calculation and implementing them in the chain of existent codes. 5) Searching through the electronic archive for data concerning the rotational bands in nuclei suspected to exhibit E(5) and X(5) symmetries. 6)) Searching through the electronic archive for data concerning the multifragmentation processes. 7) Performing the numerical calculations. The doctorand will be helped to understand the structure of the old codes and asked to participate actively for elaborating the new ones.8) Comparing the theoretical results with the experimental data. 9) Editing a scientific paper as a result of the activities in the passed period.10) Submitting the paper to the electronic arXive of Los Alamos.11) Submitting the paper to a major journal in the field of nuclear physics.12) Results dissemination through all possible means: web page, communicating it to a conference, sending reprints to the persons which potentially are interested in the subject, mass-media, etc.13) Passing to the next objective is equivalent to iterating the steps already described.Plans are comprised by working packages which consist in summing several tasks (WP) establishing the participants responsabilities. In what follows we describe these working packages: **WP0**: Management activity is taken care by the director of the project. This activity is performed for the whole period of the project. The director of the project distributes the tasks to the members of the team. A matrix with the team members and the working packages which should clearly show the participation of every member of the team. Below, this matrix is given by the PERT diagram. In this diagram the participants are related by arrows having the following significance.Researcher which receives the arrow should present periodically a report to the one from where the arrow starts. The working time for each team member is that shown in the GANTT diagram given below. The team members participates to different working packages. Below we describe the tasks distribution among the team members. To each WP we associated a number which indicates the year and the ordering label for the objective. For example, WP081 is the symbol for the first objective from the year 2008. WP' s worked out within a certain interval of time define a stage which ends with a stage report. The reports' titles and the members responsible for writing these reports are mentioned in a separate table. The director of the project will present, at the beginning of the project run, a mobility plan which must be consistent with the buget plan. Also, he notices and monitorises the contribution of each member, the individual wage

reflecting the amount of work.The member who is responsible with the web page is Dr. I.I. Ursu. **WP081**. The dynamics of fusion with exotic nuclei: new results concerning the dipole mode in the entrance channel. Responsible P3. P1 and P4 participate.**WP082**.Chosing some parametrizations of the mean field symmetry term in terms of density. Responsible P3. P0 and P4 participate. **WP083.** Calculation of the collective photon production in the pre-equilibrium stage of fusion reaction with exotic nuclei within a classical bremsstralung formalism. Responsible P3. P0 and P4 participate. **WP084**.The study of angular distribution of the emitted photons. Responsible P3. P0 participates. **WP091**. New collective models with radial symmetry for the description of nuclear phase transitions. Responsible P1. P0 and P5 participate. **WP092**. Constracting a familly of Hamiltonians to describe simultaneously the Bohr-Mottelson Hamltonian and the E(5) model for a infinite square well. Responsible P2. P0,P1 and P5 participate. **WP093**. Writing codes for symbolic calculus to construct explicitly the octupole Bohr-Mottelson basis. Responsible P2. Participate P1, P4 and P5. **WP094**.Introducing new dynamic symmetries for the analytical description of the phase transition in odd octupole deformed nuclei. Responsible P2. P0, P1 and P4 participate. **WP095**. New solvable collective models for transitional nucleai described by differential equations which are periodic in deformations. Responsible P1. Participate P2, P4 and P5. **WP096**.The considered models will be explicitly characterized by the symmetry groups associated to the differential equations. Responsible P2. P1 and P5 participate. **WP101**. Dynamic study of the pigmy resonance within a transport model. Responsible P3. P0 and P1 participate. **WP102**. For isolated exotic nuclei we shall analyze the possibility of exciting a pygmy resonance by preparing the adequate initial conditions in the momentum space or in the phase space. Responsible P3. P1 and P4 participate. **WP103**.We shall analyze the evolution of these properties with the ratio Z/N as well as the used symmetry energy. Responsible P3. P0 and P2 participate.**WP104**. Comparison with other treatments . Responsible P3. P1 and P4 participate. **WP105** We shall obtain coherent states for multipole solvable potentials. Responsible P2. P0 and P1 participate. **WP106** We shall construct coherent states for the multipole chain of the Bohr Mottelson model. This will be achieved in both, holomorphe and vectorial realization. Responsible P2. P0 and P4 participate.**Wp111.** Determining the semiclassical spectra as well as the quantal correction series for a family of multipole collective models, rotational models and Lipkin like models. Responsible P2. P4 and P5 participate. **WP112** The study of classical and thermodynamic limits**.** Responsible P1. P2 and P4 participate.**WP113** Within geometric quantization we shall construct dynamic symmetry and supersymmetry algebras through differential operators on orbits of coherent states.Responsible P2. P0 and P1 participants.

7.4. Necessary resources:7.4.1 Human resource 7.4.1.1. Project manager

7.4.1.1.1 Scientific competence of the project manager

Dr. C. M. Raduta: Got the degree in theoretical physics, 1996, with the grade 9.93**.** Became Master of Physics in 1997 at Bucharest University and also got the Master of Science degree at the Ohio State University (OSU), Columbus, OH in 2000 (with a thesis in the field of Solid State Physics)
He also got the title of Master in Business Administration (MBA) in Columbus, OH, at Fisher Business School (OSU) (among the first 20 in USA). He got the phD at Bucharest University with the thesis *Fully renormalized pnQRPA equations.Unified description of $2\nu\beta\beta$ decay of spherical and deformed nuclei.*
He has a rich experience in teaching, beeing Graduate Teaching Assistent at The City University of New York (1997-1998) and The Ohio State University, Columbus (1998-2002), taking care of laboratories and seminars for students in the 1-st, 2-nd, 3-rd and 4-th year of study. He published four beletristic books 2002, 2003, 2004, 2007. He is coauthors of two books for physics which appeared in 2007:1) Fundaments of Nuclear Theory (555 pp) and 2) Elements of special relativity (185pp). He got also specialized in Educational Physics where he published several papers and wrote a PhD thesis which has to be defended at The Ohio State Universitaty (OSU). Has 35 scientific papers from which 25 appeared in ISI journals. He acumulated 22 ISI points and he candidates for a senior reasearcher II position in the competition which is just running.In the passed recent time he was very active in the field of theoretical nuclear physics where he got semnificative results in the following directions:a) The full renormalization of the pnQRPA equations. b) octupole deformed nuclei c) double beta decay d) coherent states for the SU(2) group and the semiclassical treatment of the triaxial rigid rotor. It should be mentiond that the fields b) and d) are closely related to this project. Among the remarkable results obtained we mention: a) he provided the first fully renormalized pnQRPA equations by taking into account the scattering terms in the expression of the phonon operator b) He is coauthor of the most performant phenomenological model called ECSM, which is able to describe simultaneously 8 rotational bands, four of positive and four of negative parity.c) He obtained a realistic dscription of the double beta decay from ground to ground and from ground to 2+ state, by using a projected spherical single particle basis which defines a generalized shell model, proposed by Prof. A. A. Raduta. Results have been presented not only in those 35 papers but also in the electronic arXive from Los Alamos or by talks at international conferences..Here is the list of most significative 5

papers from the latest 3 years: [1]New results for the fully renormalized pnQRPA formalism, **C. M. Raduta** and A. A. Raduta, **Nucl. Phys. A 756 (2005) 153-175.[2]**Simultaneous description of four positive and four negative parity bands, A. A. Raduta**,** Al. H. Raduta and **C. M. Raduta**,**Phys. Rev. C74 (2006) 044312.[3]** Description of positive and negative parity dipole bands in octupole deformed nuclei, A. A. Raduta**, C.M. Raduta** and Amand Faessler, **Phys. Lett. B, 635 (2006) 80-84.**[4]Unified descriptionof the double beta decay to the first quadrupole phonon state in spherical and deformed nuclei, **C. M. Raduta,** A. A. Raduta**, Phys. Rev. C 76, 044306, (2007).[5]** Semiclassical description of a triaxial rigid rotor, A.A.Raduta, R. Budaca, **C.M.Raduta**, **Phys.Rev.C, 76,064309,(2007).**

Information about the coordinating institute.IFIN-HH, the bigest national research and developing institute (with a weight of 10% of national scientific production), performs both theoretical and experimental activities in the fields of physics and nuclear engineering as well as of conexe domains like astrophysics and elementary particles, mathematical and computational physics, atomic physics, solid state physics, the life and enviroment physics, etc. IFIN-HH has international collaboration agreements with prestigeous institutes (CERN, GSI Darmstadt, IUCN Dubna, INFN Italia, IN2P3 Franta and others) which involve high level researchers, ensure the connection to the hot subjects on the market and allow the use of the biggest laboratories in the world.In the last three years IFIN-HH achieved, or is participating at, about 118 national projects (CEEX 1 and 2, coordinates 70 of them and is partener for 48) and over 20 international projects (from which 5 FP6 and 10 FP7 – under evaluation) which, in fact, justifies the expertise in the specific fields and the management quality.

7.4.1.1.2. Managerial competence of the project manager

The project director has been and is currently an active member of several national as weel of one international project. These are listed below :
1) *Static and dynamic properties of superdeformed nuclei. New symmetries for nuclear systems*.
grant A,CNCSIS , 2006-2008, value: 90.000 RON. *2) Frontier research in nuclear and subnuclear physics*. **Program Ideas, valid from 2007 to 2010, value: 1.000.000RON.** 3). *Science and society. Ofers and expectations, acronim FAPT*, **Program Capacitati, Modul II, project nr 66CP II/14.09.2007, value 600 000 RON, valid in the period 2007-2010. 4)** *Excellence researches in the field of nuclear structure and double beta decay.* **Program: Ideas, Acronim: CEDSNDBD, Code of project: 7, 2007-2010, Value: 1.000.000 RON. 5)** *Semiclassical and quantal properties and symmetries of structure and dynamics of nuclear and atomic physics.* **Program : Nucleu , Code of project: PB-03-20-01-02, 2000, Value : 195.011 RON 6)** *The structure and dynamics of nuclear and atomic systems.* **Program: CERES**, **Code of project : 2-14/2002, 2002, Value: 329.891 RON 7)**. Upon some fundamental aspects of the structure and dynamics of atomic systems. **Program: CERES, Code of project: 40189/2004, 2004, Value : 105.000 RON. 8)** *Nuclear structure, double beta decay and dynamics of processes like fusion, fission and nuclear multifragmentation* **Program: Ceex05-D11-0, Acronim: SNDBDDFFM, 2005, Value :1500000 RON. 9)** *Theoretical and Mathematical Models for the description of some fundamental aspects of some nuclear and atomic processes***.** .**Program: Ceex05-D11-03, Acronim: MTMDAFPAN, 2005, Value: 750000 RON. To these project he contributed by stage reports :**1) Description of double beta decay in deformed nuclei with a projected spherical single particle basis. 2) Description of double beta decay to excited states. 3) Description of collective bands of negative parity 4) Quantitative description of 8 rotational bands, four of positive and four of negative parity. 5) The full renormalization of the pnQRPA equation which obey the Ikeda sum rule 6) Description of wobbling motion in triaxial nuclei. He is a member in the team which benefits of the international grant : **1.** *Collective motion and phase transitions in nuclear many body systems. New features of the double beta decaying nuclei*, **grant DFG, valid for the period of 2007-2010.** His results were presented in three conferences as invited papers which were included in the conference proceedings: Praga 2000, Predeal 2006, Vico Equense 2007**.** He is very actve member of the research center *Theoretical Physics* of the Bucharest University. Due to his MBA qualification he carries the center manager tasks, being responsible with the center web page as well as with the financial work of the group (16 members). In 2004 he got through a competition the position of Business Development Executive at Rompetrol which he kept for 6 months. Within this period he elaborated the project *Business War Game* which allowed for an efficient selection of graduate students from Economics faculties to be employed by Rompetrol. The project was very successful and is still used by the big companies all over in Romania.

7.4.1.2. Research team. List of the research team members:

Crt. No.	Surname and first name	Year of birth	Didactic /scientific title *	Doctorate * *	Signature
1	Raduta Apolodor Aristotel	1943	Profesor	Da	
2	Gheorghe Alexandru Cezar	1943	CPI	Da	
3	Baran Virgil	1966	Profesor	Da	
4	Ursu Ioan	1957	CPII	Da	
5	Buganu Petrica	1983	Asistent de cercetare	Master. Va fi doctorand incepand cu luna iunie 2008	

7.4.1.2.1. Experienced researchers : (Without the project manager)

The team members have a rich experience in the proposed fields. During the years they joined together in several fruitful collaborations. One may say that the team is strong three members have been PhD students of Prof. A. A. Raduta and one (A..C.G) is collaborating with Prof. A. A. Raduta for more than 30 years already. We shall describe separately the experience for each member.

A.A. Raduta. The fields of research in which his contributions are recognized as prioritary:

A) Microscopic description of the quadrupole-octupole collective motion . B) The explicite dependence on the gamma variable of the eigenfunctions of the Bohr-Mottelson Hamiltonian . C) The Coherent State Model (C.S.M.) for the description of the ground, beta and gamma bands for transitional and deformed nuclei, including the high spin states. D) A new boson expansion for the quasi-spin algebra. E) The generalized coherent state model (G.C.S.M.). F) Toward a new shell model .

H) Contributions to the description of the double beta decay. G) Using the tensorial forces of Skyrme for finite nuclei, one has been investigated the possibility of having a density isomer state. I) The classical origin of the many body formalisms like BCS, RPA, boson expansion, has been proved. J) The description of the alpha clustering phenomenon in heavy nuclei. K) Semiclassical investigation of the spin excitations in nuclei . L) The study of nuclei with octupole deformation.M) Semiclassical studies of the boson Hamiltonians: the regular and chaotic behaviour. N) Fully renormalization of the pnQRPA equations. O) A new description of the deformed atomic clusters. P) New phenomena in nucleon systems with pairing p-n interaction. R) New results for the description of the isospin degrees of freedom . S) New symetries for the nucleon systems. SS) New quantization methods of constrained systems .In the brackets, the ordering number of the papers in the attached list is mentioned.

Scientific papers: *187, from which 140 are published in foreign journals*.

He organized, as a director, 6 International summer schools and editted the corresponding proceedings:[1] Critical phenomena in heavy ion physics, Brasov International School 1980, Central Institute of Physics, Bucharest, Romania, 1124 pages; Editors: A.A. Raduta, G. Stratan. [2] Symmetries and Semiclassical Features of Nuclear Dynamics, Proceedings, 1986, Springer Verlag, 465 pages; edited by A.A. Raduta .[3] New Trends in Theoretical and Experimental Nuclear Physics, World Scientific, Singapore, 1992, 549 pages; edited by A.A. Raduta, D.S. Delion and I.I. Ursu . [4] Collective motion and Nuclear Dynamics, World Scientific, Singapore,1996, 585 pages; edited by A. A. Raduta, D. S. Delion and I. I. Ursu. [5] Collective Motion and Nuclear Dynamics, Proceedings of short communications given at International Summer School, Predeal, 1995,Romanian Journal of Physics, vol. 41, no 1,2, 1996, 210 pages, edited by A. A. Raduta. [6] Structure and Stability of Nucleon and Nuclear Systems, Predeal 1998,585 pages, eds. A. A. Raduta, S. Stoica and I. I. Ursu, World Scientific,Singapore.[7] Structure and Stability of nucleon and nuclear systems, Predeal 1998, Proceedings of short communications, Romanian Journal of Physics, vol. 44, no.1,2,1999, 332 pages, edited by A. A. Raduta, S.Stoica and I.I.Ursu.[8] Collective Motion and Phase Transitions in Nuclear Systems, Predeal 2006, 700 pages, edditted by A. A. Raduta, V. Baran and I. I. Ursu, World Scientific, Singapore. [9] Collective Motion and Phase transitions in Nuclear Systems, Predeal 2006, proceedings of short communications 250 pages, Romanian Journal of Physics, to appear in July 2007 (volume dedicated to Acad. Prof. Dr. A. Sandulescu on the occasion of his 75-th aniversary)**.**

Monographies: 5. Chapter in the book: Coherent State Model for several collective interacting bands, 70 pages, chapter in the book **Recent Research Developments in Nuclear Physics**, published by the prestigeous Publishing House Transworld Research Nework, India, ISBN:81-7895-124-X. **Books**

published in 2007: 1) Fundaments of nuclear theory (555 pages), Bucharest University Publishing House, A.A.Raduta, C. M. Raduta 2) Elements of special relativity (185 pagini), Bucharest University Publishing House, A.A.Raduta, C. M. Raduta. **Member in editorial boards:** Romanian Journal of Physics, European Nuclear News (1996-2007)**. Awards: 1974, got the prize** "Dragomir Hurmuzescu" delivered by the Romanian Academy for a set of publications about "The microscopic description of the collective quadrupole-octupole double phonon states". **2000.By a presidential decree,** signed by The Romanian President Emil Constantinescu, for outstanding merits in developing the research and the progress of science and technology he was awarded with the National Order **"Pentru Merit" with the degree of officcer.1975-1976:** Senior Humboldt Fellow at the Goethe University, Frankfurt/Main. **2002 and 2007.** He was asked by **the Nobel Commitee**, Royal Academy of Sweden, Stockholm, to propose three people for the Nobel Prize for Physics for the year 2003 and 2008, respectively.**2002**: The prize awarded by the Humboldt Foundation "Stability Pact in South-East Europe".**In 2008**, by a strong competition he got a position of **Distinguished Professor** at The Complutense University, Madrid. He was director of several international (Copernicus, 1994, NATO,2001,DFG, 2001, 2004, 2007) and national (Nucleu, Ceres, 2, CEEX 2, Idei 1) projects. **5 significant papers published in the latest three years** : **[1**] Remarks on the shape transition from spherical to deformed gamma unstable nuclei, **A. A. Raduta**, et al., Jour. Phys. Phys. G. 31 (2005) 337. **[**2]Coherent state description of the shape phase transition in even-even Gd isotopes, **A. A. Raduta** et al**.,** Jour. Physics G, 31(2005) 873**. [3]**Quantum deformation of the Dirac bracket, **A. A. Raduta** et al.,, Phys. Rev. D 73, 025008 (2006).**[4]**New results for the two neutrino double beta decay in deformed nuclei with an angular momentum projected basis, **A. A. Raduta**, et al., Phys. Rev. C 69, (2004) 064321**.[5]**Solvable models for the gamma deformation having X(5) as limiting symmetry. Removing some drawbacks of the existent descriptions, **A. A. Raduta,** et al**, Phys. Lett. B 648 (2007) 171. A. C. Gheorghe.** Over 80 scientific papers with more than 300 citations; 50 international conferences , lectures and seminars. **Research projects**. Member in a team : 2 international projects, 6 projects CEEX, 5 projects CERES, 3 projects NUCLEU, 3 grants**. Other competences:** a) Mathematics: differential geometry, algebraic geometry, theory of induced representation, invariants theory, distribution theory, global analysis.b) Informatics: codes of symbolic calculus, the theory of quantum computers. **Specialisation**: Axiomatic theory of relativistic fields and the theory of the Lorentz invariant distribution in the Theoretical Physics Laboratory of IUCN Dubna (1971-1974). Other mentions: Award **Dragomir Hurmuzescu from the Romanian Academy for** *Contributions to the collective motion in nuclei* (1980). **Specific fields of research**: a) Spinor Theory, b) Model independent results in the elementary particle physics, c) Relativistic quantum field theory, d) Algebraic methods in nuclear physics, e) The nuclear collective models geometry, f) Geometrical construction of the symetry groups representations, g) Geometric quantization, h) Quantum states geometry, i) Classical and quantum mechanical nonlinear systems, j) Theory of magnetic traps for charged particles, k) Algebraic methods for studying the quantum computers. **5 significant papers**: [1]A. C. Gheorghe, A. A. Raduta , et al., Solvable models for the gamma deformation having X (5) as limiting symmetry. Removing some drawbacks of the existing descriptions, Phys. Lett. B 648 (2-3), 171-175 (2007).[2**]** A. C. Gheorghe, A. A. Raduta , et al, Remarks on the shape transition from spherical to deformed gamma unstable nuclei, J. Phys. G: Nucl. Part. Phys. 31, 337 (2005) [3**]** A. C. Gheorghe, A. A. Raduta, New results for the missing quantum numbers labeling the quadrupole and octupole boson basis, J.Phys. A: Math. Gen. 37, 10951 (2004). [6] S. Berceanu, A. C. Gheorghe, On equations of motion on Hermitian symmetric spaces, J. Math. Phys. 33, 998 (1992).[5] Semiclassical treatment of a cranked triaxial rotor, A. Gheorghe, A. A. Raduta, et al., Nucl. Phys. A 637 (1998) 201. **V.Baran** published ***90 scientific papers*** of which **58 appeared in some of the most important ISI journals from abroad**. His works are very well appreciated in the scientific community as proved by more then ***700 citations*** **reported in ISI data base**. His original contributions covered several domains: a) Semiclassical studies of quadrupole boson Hamiltonians, describing nuclear surface motions.b)Classical and quantal chaos in Hamiltonian systems;c) Fusion reaction dynamics between heavy ions and collective motions in the framework of microscopic transport models of Boltzmann-Nordheim-Vlasov type;d) Zero to first sound transition in two-components Fermi liquids and properties of Giant Dipole Resonances in hot nuclei; e) Landau Fermi liquid theory applied to the instabilities in binary systems as well as to the kinetics of phase transitions with applications to the nuclear multifragmentation phenomena; f) Dipole bremsstrahlung during the preequilibrium stages of the fusion reactions between heavy nuclei ;g) Isospin dynamics at intermediate energies; neck fragmentation reaction mechanism and isospin diffusion; h)The role of scalar-isovector delta meson and other elementary particles on the symmetry energy of nuclear; i)Asymmetric nuclear matter equation of state studies in the framework of effective field theories including hadronic and mesonic degrees of freedom; J)Pions production: the role of equation of state of asymmetric nuclear matter in heavy ions collisions at relativistic energies. **5 significant papers :** 1) Reaction Dynamics with Exotic Nuclei, Baran V, Colonna M, Greco V, M. Di Toro Phys. Reports 410 335-466 (2005) (review work, more then 75 ISI citations) 2) Spinodal decomposition of low-density asymmetric nuclear matter, V.Baran, M. Colonna, M. Di Toro and A.B. Larionov, *Nuclear Physics A* 632 (1998) 287-

303 (over 92 ISI citations) 3)Isospin effects in nuclear fragmentation, V.Baran, M. Colonna, M. Di Toro, V. Greco, M. Zielinska-Pfabe, H.H. Wolter, Nucl. Phys. A703 (2002) 603-632 (over 92 ISI citations) 4)Collective Dipole Bremsstrahlung in Fusion Reactions ,V. Baran, D.M. Brink, M.Colonna, M. Di Toro Phys. Rev. Lett. 87 (2001) 182801 (over 10 citations) 5)Nuclear Fragmentation: Sampling the Instabilities of Binary Systems, V. Baran, M. Colonna, M. Di Toro, V. Greco Physical Rev. Lett. 86 (2001) 4492-4495 (over 35 ISI citations). **Invited lectures at Int. Conf.** :Trento 1996, Bologna 2000, Catania 2001,Caen 2004, Predeal 2006, Gordon Research Conference. **Research stages i**n Italia, Germania, Marea Britanie, Grecia si SUA. International collaborations with recognazed personalities: Prof. A.A. Raduta (Bucharest), Prof. D.M. Brink (Univ. Oxford, Anglia), Prof. M. Di Toro (Univ. din Catania, Italia), Prof. M. Z. Pfabe (Smith College, SUA), Prof. H. Wolter (Univ. of Munchen, Germany), Dr. M. Colonna, Dr. V. Greco (Laboratori Nazionali del Sud, Italia). Membru al unor colaborari internationale de amploare in proiecte experimentale desfasurate la Catania si Napoli. **He is professor** at Physics Faculty, UB. Starting with 2007 he is PhD supervisor. **Award** :In 1999 – got the prize **Horia Hulubei** from the Romanian Academy. **Project Director**:1) International research contract (Italia, art. 23) ; 2002-2003 (un an) 25000 euro ; Istituto Nazionale di Fisica Nucleare, Italia si Universitatea din Catania (Italia)2) Proiect CEEX, 74/2006, ANTIOX: Cells and subcells effects of some natural antioxidants under normal conditions and under stress; coordinator UMF Carol Davila; 2006-2008; 1.500.000 RON (partner *responsible UB*)3) Project Idei_946, Frontier research in nuclear and subnuclear physics 1000000 RON Member in a team (last 5 years) Program C2/C14,Program Nucleu 2003-2005,Program C4 2004-2006;Grant Academie 2005;CEEX/D10-02/2005,CEEX/D11-03/2005,;CEEX M3,43/2006. Scientific secretary of the internacional conference *Collective Motion and Phase Transitions in Nuclear Systems*, Predeal, Romania 2006 and coeditor of the conference proceedings. He is activating as scientific advisor in the executive staff of the research center *Theoretical Physics* of the Bucharest University acreditated in 2006. Project members are granted from the projects: Ceex CD10-02/05 (coordinator IFIN-HH),CeexCD11-03/05 coordinator Universitatea din Bucuresti), Contract Nucleu, project IDEI33/05. We believe that participation to the present project will beabout 60-80% of the working time.

I.I. Ursu. Original contributions to the field of theoretical nuclear physics : a) semiclassical methods for nuclear system b) description of collective magnetic dipole states c) Description of the alpha clustering phenomenon in heavy nuclei d) collective spin like excitations.Other mentions: a) member of accepted FP7 projects, where IFIN-HH is partener: i) FP7 Facility for Antiproton and Ion Research (Acronym FAIR), Proposal reference number : FP7-211382 (2007). ii)FP7 ERA-NET for Nuclear Physics Infrastructures (Acronym NuPNET), Proposal reference number : FP7-202914 (2007).b) Organiser of noational and international scientific meetings (selected):1. Predeal International Summer School New Trends in Theoretical and Experimental Nuclear Physics August 26 - September 7, 1991; Editors: A.A. Raduta, D.S. Delion and *I.I. Ursu* ; *World Scientific (1991).* 2. Predeal International Summer School Collective Motion and Nuclear Dynamics August 28 - September 9, 1995; Editors: A.A. Raduta, D.S. Delion and *I.I. Ursu*; *World Scientific (1995*).3. Predeal International Summer School Structure and Stability of Nucleon and Nuclear Dynamics August 24 - September 5, 1998; Invited Lectures. Editors: A.A. Raduta, S. Stoica and *I.I. Ursu* ; *World Scientific (1998*). 4. Conferinta Nationala de Fizica 2005, Bucuresti. 5. Predeal International Summer School Collective Motion and Phase Transitions in Nuclear Systems, 28 august-9 septembrie 2006; Invited Lectures. Editors: A.A. Raduta, V. Baran and *I.I. Ursu* ; *World Scientific (2007).* 6. 5th Interna-tional Balkan School in Nuclear Physics - Physics with Radioactive Beams, Brasov, 7-14 septembrie 2006. c) author of methods of promoting the science image, science communicator: Jurnalul Electronic al MedC 2005 si Supliment JE 2005, Jurnalul Electronic al ANCS 2006, achieved in collaboration with cu A. Dorobantu the documenting film F.A.P.T. (Fizică-Afaceri-Politică-Tehnologie) - a unitary presentation of the physics institutes from Magurele campus as well as of the physics institutes from all over the country aiming at making explicite the *Physics Offer* to the potential industrial consumers, presenting folders IFIN-HH,ANCS, sigla and banner ANCS, levelet ANCS, ROST, INFRATECH, JE ROST etc.

7.4.1.2.2. Early stage researchers

Petrica Buganu, master in Physics from 20th of february 2008, is employed temporary at IFIN-HH, Department of Theoretical Physics. He prepared his disertation under the supervision of Prof. Dr. A. A. Raduta. The disertation title: *Description of nuclei which satisy the X(5) symmetry with the help of spheroidal functions* . In June 2008 he will be enrolled for PhD studies with Prof. Dr. A. A.Raduta. He will prepare his PhD in the field of *Description of phase transitions in finite nuclei within solvable models*. He will be gradually introduced to the subjects of the project. He will follow a training program learning special topics from Nuclear Structure and Nuclear Radioactivities. In parallel, he will have at his disposal all codes of our group concerning the spectroscopic properties of octupole deformed nuclei as well as the double beta decay. He will be involved full time in this project, this beeing the only financing resource for

him. He will check the analytical calculations performed by the seniors of the team. Also he will try the satisfaction of having himself a task of elaborating a theoretical work necessary for accomplishing the project objectives. For each paper to which he has a visible contribution he will be stimulated with prizes. For his PhD thesis he will receive the following subject: *The study of the critical points for the phase transitions in octupole deformed nuclei by means of spheroidal functions*. It should be mentioned that Mr Buganu consulted already a vaste bibliography in the field of phase transitions and, moreover, he has a consistent training in manipulating the codes of Mathematica for prolate spheroidal functions. We hope that involving him in this project will be profitable for him and that this collaboration will be his first step toward a top research carrier in nuclear physics.

7.4.2 Other resources 7.4.2.1. Financial resources

Staff expenses: Experienced researchers, including the project director will be involved in project by 85% from their full working time while the early stage researcher will work full time for the present project. Consequently they will receive, within the whole period of 36 months the following wages per month: 1)Experienced researchers 3000 lei 2) the early stage researcher 1600 lei. For an exchange rate 1EURO=3.66 lei, these correspond to the following brut salaries: 1) Experienced researchers 819 EURO,2) The early stage researcher 438 EURO.
Mobilities: For this budget we have foreseen 25000 lei . This amount is obtained by summing the partial expences: a)transportation 12000 lei b) lodging -10000 lei c) perdiem 3000 lei.
Logistic: 2008: software-4000 lei, antivirus-1000 lei, consumables-1000 lei, books-2000 lei.
2009: consumables-8000 lei,books-2000 lei,2010: consumables-8000 lei,books-2000 lei.
2011: software-10000 lei, antivirus- 4000 lei, consumables- 4000 lei, books-2000 lei.**TOTAL:48000 lei**

7.4.2.2. Available infrastructure (the quality of the existent research infrastructure)

The group has the following equipments: 3 performant computers (one year old), 5 laptops (one year old). Also the team may access the facilities from the Center of Information Technologies and Comunications of IFIN-HH using a cluster of several station which is devoted to the study of complex physics phenomena through a a distributed numerical calculations of high level performance. We intend to use one of the cluster component as a host for the web page associated to our project. The experienced researchers together with the director of the project have their offices in two rooms equiped with new furniture except the book-shelves of prof. Raduta which is about 40 years old.The young researchers has a performant computer, which is less than one year old. All computers are equipped with the software which is necessary for their training in the problems related to the project: Compilers for fortran or C++, grafic, editors for linux, latex, word, excel, power point, etc. The man who is in the initial stage of research works in a large office which has to be equipped with new furniture, a new pavement and also to be painted. All mentioned computers are connected to the internet through the net of IFIN-HH. In this way team members can access online the major journals of Nuclear Physics: *Nuclear Physics A, Physical Review C, Physical Review Letters, Physics Letters B, Annals of Physics (NY), Journal of Physcis G, European Journal of Physics A, etc*. Also the members of the project team have at their disposal the library of the Institute of Atomic Physics which is the richest library from Bucharest. Also they have access at the library from the Physics Faculty. We take the risk of stating that we have all necessary conditions to achieve a high level research

8. Project management:

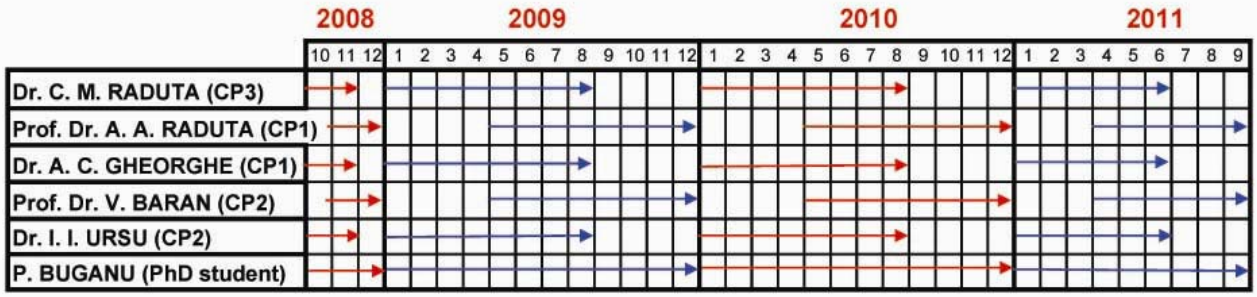
8.1. Work plan. Obiectives and activities

Year *		Goals (Name of the obiective)	Associated activities
2008	1	**WP081**. *Fusion dynamics fo exotic nuclei: new results concerning the dipole mode at preequilibrium in the entrance.*	The construction of the project web page. Documentation upon trhe latest theoretical and experimental results published in connection with the project.Participate P3, P1, P4.
		PS082 *Coosing a parametrization with respect to density for the symmetry term of the mean field.*	Selecting the exotic nuclei for which the fusion process will be studied and fixing the energies in the entrance channel in close relations with the recent experimental data. All possible parametrization with density of the symmetry energy from the mean field will be considered. Prticipate P3,P0, P4
	2	**PS083**. *Calculation of the photon production in the preequilibrium stage of a fusion reaction with exotic nuclei within a classical bremsstrahlung.*	Preparing the numerical codes for transport equations and testing the initial conditions. Executing the numerical codes for chosen energies and impact parameter varying from zero to that value where the deep inelastic reaction may take place and for various parametrization of the symmetry energy term. Analyzing the numerical results and interpreting the results. Participate P3, P0 and P4.
		PS084 *The study of the angular distribution for the emitted photons*.	Organising group seminars where the new results are presented A scientific paper will be editted. Result disemination will be achieved by depositing the article in the electronic arXive from Los Alamos. The article will be submitted for publication.
2009	1	**WP091**.*New multipolar collective models with radial symmetry for the analytical description of the nuclear phase transition.*	Using the dynamic symmetry groups of the Schroedinger equation, we shall classify the Hamiltonians in the radial variables which admit solvable or partially solvable potentials. Responsible P2. Participate P1, P0 and P5.
		WP092 *Construction of a family of Hamiltonians which might describe both the Bohr-Mottelson model and the E(5) model for a square well potential*.	We shall explicitly obtain the energy spectra and the corresponding eigenfunctions of the Hamiltonians mentioned above. In cthe case considered in the Iachello model, we shall orthogonalized completely the family of the wave function. Responsible P2. Participate P0 P1, P5.
	2	**PS093** *Elaborating codes for symbolic calculus to be used for constructing explicitly the Bohr-Mottelson octupole basis..*	We shall elaborate codes for symbolic calculus in order to construct explicitly the octupole Bohr-Mottelson basis. Responsible P2. Participate P4 si P5.
		PS094 *Introducing a new class of dynamic symmetries for an analytical description of the phase transition for odd and octupole deformed nuclei*.	Considering potentials which are independent of the angular variable and using the result of a recent paper of our group we shall calculate explicitly the spectra and the transition probabilities. Theoretical results will be compared with the corresponding experimental data.Responsible P2. Participate P1,P0 si P4.
			Updating the web page. The task go to P4 and P5

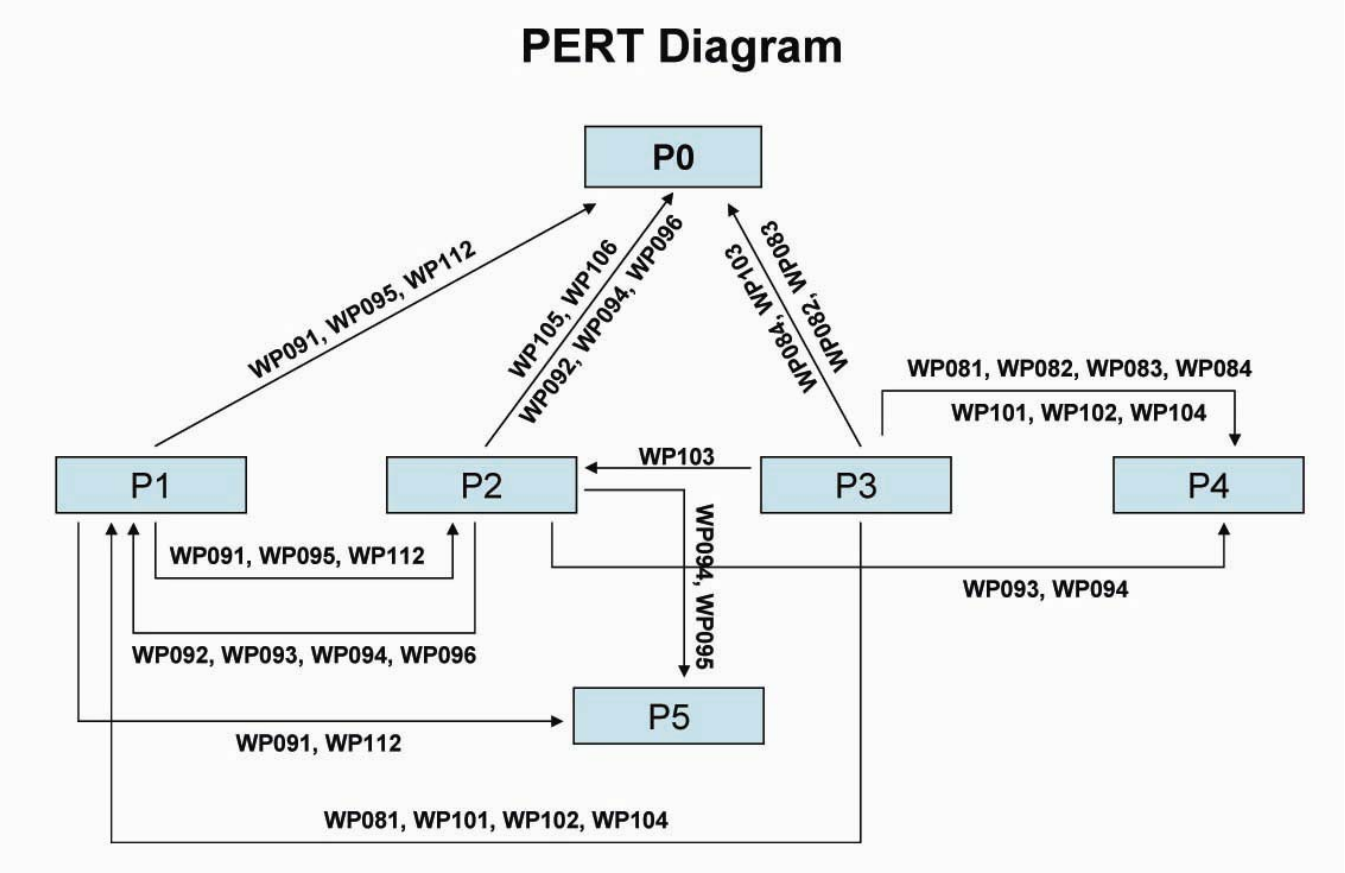
	3	**PS095** *New collective solvable models for transitional nuclei described by deferential ecuations periodic in deformations.* **PS096** *The considered models will be explicitly characterized by the symmetry groups of the associated differential equations*.	We shall introduce a new class of dynamic symmetries for an analytical description of the phase transition in odd and octupole deformed nuclei. Responsible P1. Participate P0, P2 si P4. Writing a new scientific paper. Responsible P1. Participate P0, P2, P4 and P5. Results disemination by participating at international conferences. Responsible P0. Participate the whole group.
2010	1	**PS101** *The study of dynamic for the Pigmy resonance within a transport model.* **PS102** *For isolated exotic nuclei we shall analyse the possibility of exciting the Pigmy resonance by preparing suitable initial conditions in momentum space or phase space.*	These properties will e analysed as function of Z/N and symmetry energy. Preparing the numerical codes. Responsible P3. Participate P1, and P0. Numerical applications for several reactions. *Responsible P3, Participate P1and P4.*
	2	**PS103** *The evolution of such properties as function of Z/N and symmetry energy will be analyzed..* **PS104** *Comparison with other treatments of the same phenomenon.*	Considered properties are studied as function of Z/N and symmetry energy. Writing a scientific paper. Responsible P3. Participate P0 si P2. Working stage abroad. Responsible P3. Participate P1 and P4.
	3	**PS105.** *We shall obtain coherent states for multipolar solvable potentials which are not depending on angular variable.* **PS106** *We shall construct coherent states for the multipolare chain of collective model of Bohr-Mottelson by both the holomorph realization and vectorial realization.*	Within the geometric quantization procedure we shall construct dynamic symmetry and supersymmetry algebras realized through differential operators on orbits of coherent states. We shall elaborate codes of symbolic calculus. Responsible P2. Participate P0 and P1. In the case of compact groups, we shall obtain semiclassical spectra by considering as trial functions from the uniparametric groups generated by complexifying the dynamic Lie algebra. Results will be compared with the Maslov corrections. Responsible P2. Participate P0 and P4.
2011	1	**PS111.** *Determining the semiclassical spectra as well as the quantum mechanical correction series for a family of collective multipolar models,* *Rotational models and Lipkin type models.*	Results will be compared with asymptotic quantum spectra which depend analytically on the model parameters. Coherent states, semiclassical spectra and asymptotic quantum spectra. Responsible P2. Participate P4 and P5.
	2	**PS112** *Study of classical and thermodynamic limits.*	Working stage abroad. The results will be included in a scientific paper.Responsible P1. Participate P2 si P4. Updating the project web page. Task for P0 and P4.
	3	**PS113** *Within the geometric quantization we shall construct dynamic symmetry and sypersymmetry algebras through*	We shall construct coherent states for the euclidian multipolar model.

		differential operators on orbits of coherent states.	We shall coherent states for the multipolar group chain of the Bohr-Mottelson collective model in both the holomorph and vectorial realization Responsible P2. Participate P0 and P1. Results will be disseminated by presenting them in international conferences and depositing them in the electronic arXive from Los Alamos.

GANTT Diagram



OBS: a) 66% of the working time of the researchers with large experience will be allocated to this project.
b) 100% of the working time of the PhD student will be allocated to this project.


PERT Diagram
P0
P1
P2
P3
P4
P5
WP091, WP095, WP112
WP105, WP106
WP092, WP094, WP096
WP084, WP103
WP082, WP083
WP081, WP082, WP083, WP084
WP101, WP102, WP104
WP103
WP091, WP095, WP112
WP092, WP093, WP094, WP096
WP094, WP095
WP093, WP094
WP091, WP112
WP081, WP101, WP102, WP104

	P0	P1	P2	P3	P4	P5	Om-luna
PS081		1.3		2.6	1.3		5.2
PS082	1.3			2.6	1.3		5.2
PS083	1.3			2.6	1.3		5.2
PS084	1.3			2.6	1.3		5.2
PS091	2.6	1.3	2.6			5.2	11.7
PS092	2.6	2.6	2.6			5.2	13
PS093		1.3	2.6		2.6	5.2	11.7
PS094	2.6	2.6	2.6		2.6		10.4
PS095	2.6		2.6			5.2	10.4
PS096	2.6	2.6	2.6			5.2	13
PS101		1.3		5.2	2.6		9.1
PS102		1.3		2.6	2.6		6.5
PS103	2.6			2.6			5.2
PS104		2.6		2.6	1.3		6.5
PS105	1.3	1.3	2.6				5.2
PS106	1.3		1.3		1.3		3.9
PS111		2.6	1.3		2.6		6.5
PS112	1.3	2.6	1.3		2.6	10	17.8
PS113			1.3				1.3
TOTAL	23.4	23.4	23.4	23.4	23.4	36	153

This table shows the participation of the team members to WP in a time interval given in units of man-month.

8.2. Project feasibility (having in mind the human resource (experience) and other resources involved into the development of the based on previous confirmed capacity project

Taking into account the team experience in the involved fields the project feasibility is a sure thing. From the presentation of the experienced researchers it clearly results a rich experience in the filds of phase transitions (A.A.Raduta, A. C. Gheorghe, C.M.Raduta, I.I.Ursu), coherent states and quantization procedures (A.A.Raduta, A.C.Gheorghe, C.M.Raduta) as well as of nuclear multifragmentation (V. Baran, A.A.Raduta) . As a matter of fact this is confirmed by their publication lists in these directions. The quaestion which may arise is whether the work volume could be covered by the team members. The answer to this question is certainly yes. Indeed this comes out immediately taking into account that the number of publications per year for each membre of the team is larger than that mentioned in the realization plan of the project.

Will be the formative scope of the project por the participating PhD student achieved ? The answer is again yes taking into account the training plan and the way he is required to solve the project tasks.

The facts that he was already employed and that he is offered a chance to work in a high level scientific medium, with work stages abroad, are attractive features which will stimulate him for a motivated work to improve his qualification. Another feasibility index is that of international cooperations. In this context we mention that we have permanent collaboration relations with Intitute for Theoretical Physics of Tuebingen University (Prof. A. Faessler), Institute of the Structure of Matter, CSIC, Madrid (Prof. E.Moya de Guerra), Departments of Physics and Astronomy of Rutgers University (Prof. L. Zamick), The Institute LNS from Catania (Prof. Dr. M.Di Toro). The relations with the mentioned personalities are so good that whenever we meet unclear problems in a certain field we launch a debate on that matter through e-mail (It is to be mentioned that at their turn they proceed in the same manner). Many times such debates led to papers which were favorably received by the international community.

Conclusion : The experience and the quality of the scientific papers published by the members of the team in prestigeous journals for nuclear physics, with large ISI impact factors, proves their expertise and capability to accomplish the proposed objectives**.** The director of the project together with the experienced members will shall take care of : i) strategic planning ii) Monitorise the project progresses and take the right measures to correct for the deviations from the realisation plan. iii) Asure the scientific quality and the conformity with the proposed objectives. iv) Check on the financial and budget matters. v) a permanent contact with the contractant authority. vi) Presentation of the stage report in due time.

8.3. Results dissemination plan

The dissemination plan for the results obtained by the project refers to both the running period of the project and the interval which follows. The new results which are to be published will be deposited first in the electronic arXive from Los Alamos. The second step consists of submitting the paper for publication to one of the journals of outstanding reputation: Nuclear Physics A, Physical Review C, Journal of Physics G. In every paper we shall mention in *Acknowledgement*, the fact the the work was supported by the aferent contract. All dissemination actions will be made in agreement with the

intelectual property
and the ethic code of researcher. According to the mentioned journals rules, publishing the articles after their acceptance due to the referee report requires the Copy Rights transfer to the respective journal. We shall obey to this requirement. We shall exclude from our paper any statement which has been launched before by other people. Any overlap with preceeding achievements will be included only in the case the idea paternity will be cited and also the difference with respect to what was already published is pointed out. A web page of our project will be created where all information related to the project as well as the achievements will be described:
- objective presentation and the realization methodology
- the stage report will be presented,
- watching the progresses of the proposed objectives,
- the relevance of the treated subjects and the results obtained,
- attracting the young researchers to fundamental research in the field of theoretical nuclear physics.

A mobility plan will be elaborated such that each member to participate at two conferences in a year. The results obtained so far by the project will be communicated there.
We shall insist for an oriented dissemination of the results to those persons which work in a field which is close to ours, which results in using further our results for the knwoledge exploring process.
The important results will be comunicated in the institute seminars as well as in the seminars of the Physics Faculty. The publication reprints will be posted to those persons which work on similar problems.
Also, will be sent to Romanian personalities from other centers from Romania with the scope of identifying Romanian groups which might use our results. The outstanding results will be mediatized at radio of television, taking advantage of the generous help of Dr. Alexandru Mironov. We shall take profit of these ocasions to influence the pupils from the high school to chose physics as their profession.

8.4. If there areapplied research activities, please specify those activities and the allocated budget

Not the case.

8.5. Measures provided in order to respect the research

The research activity of the project members will take place with a rigurous obey of the law concerning the ethic behaviour code of scientific researchers, inovation and technological developing, mentioned in the law 206 from 27th of May 2004, emitted by Romanian Parliament and published in the Official Monitor nr. 505 from 4th of June 2004. We mention that our research have a fundamental and theoretical character and does not imply any aspect related to: 1) protection of the human being , 2) animal protection, 3)medium protection. Our activity excludes: a) hiding or removing the undesired results b) tayloring the results c) replacing the results with fictitious data; d) the deliberate wrong interpretation and deforming the conclusions, e) plagiating the results or publications belonging to other authors.f) Presenting deliberately the deformed results of other researchers; g) not recognizing the real paternity of a paper; h) giving wrong information in the grant applications for financial support. i) not unveiling the intereses conflict. k) not recording and / or not depositing the results or eronate recording or depositing the results. l) the information lack of the research team, before the project starts, with respect to the salary rights, responsabilities, coauthorate, rights upon the research results, financial resources and associations m) the lack of objectivity in evaluating other projects and the lack of confidentiality; n) publishing or financing several times of the same results, presenting them as scientific news. The team members will be informed about the ethic norms formulated in the law cited above. They will be also informed about the punishements mentioned in the article 14 from the same law in the case these normes are violated: a) excluding the person, or the persons, from the team; b) changing the project responsible; c) withdrawing and/or correcting all works published by violating the norms of good behaviour. Taking into account the experience of working in this team the project director expresses his belief that none of these norms mentioned above will be broken. Indeed, honesty for a scientist is a defining virtue.

CHECKING LIST

- The project manager is full time employed in the institution which proposes the project;
- The project manager has the PhD degree;
- The proposed project has obiectives and actions to be achieved during a period of 36 months;
- All the requested Annexes have been filled;
- The budget has been filled in “euro”;
- The financing request is signed by the authorized persons from the host institution.