THEORETICAL AND MATHEMATICAL PHYSICS

LABORATORY: <u>THEORY OF ELEMENTARY PARTICLES</u>

HEAD OF LABORATORY: CORRESPONDING MEMBER OF BAS, PROF. DSC EMIL NISSIMOV

The science research in the Laboratory includes various major actively developing research areas in modern theoretical and mathematical physics. Our research is conducted within the framework of a broad international collaboration with world renown science centers such as CERN (Geneva), ICTP and SISSA (Trieste), JINR (Dubna), as well as with numerous leading universities and academic research institutions from abroad

In 2014 the members of the Laboratory (co)authored **53 scientific works** altogether, among them - 30 published and 23 pending publication papers in international journals and international conference series. Throughout 2014 scientific papers of Laboratory's members have received **385 independent citations** in international science journals and conference proceedings worldwide.

Members of the Laboratory have participated in several large projects funded by Bulgarian National Science Foundation (DFNI T02/6), Bulgarian Ministry of Science and Education, as well as in various prestigious internationally funded projects - supported through bi-national academic cooperation agreements and/or funded by the European Commission programs, among them COST action MP-1210, COST action MP-1304 and COST action MP-1405.

Principal Research Areas

Area 1: Algebraic and geometric methods in quantum theory. Quantum informatics (*L. Hadjiivanov, I. Todorov, T. Palev, A. Ganchev, L. Georgiev, N. Nikolov, N. Stoilova, T. Popov, V. Molotkov, D. Nedanovski*)

The properties of electric and heat conductivity and the Seebeck coefficient at non-zero temperature are studied using the effective conformal field theory for the Laughlin Hall states in Coulomb blockade islands realized in strongly correlated two dimensional electron systems. The results are similar to those for Coulomb blockade metallic islands.

The notion of residuum of Feynman amplitudes, providing and "measuring" the obstacle to preserving dilation invariance after renormalization, is introduced. The notion is generalized for multipoint amplitudes and an operad structure is found in the space of residua of Feynman amplitudes playing a role in the structure theory of vertex algebras analogous to the residuum techniques for chiral ("one dimensional") vertex algebras.

A pair of novel difference equations, with solutions expressed in terms of Racah or Wilson polynomials depending on the nature of the finite-difference step, are considered. It is shown that the introduced equations allow the construction of new models of exactly solvable quantum dynamical systems such as spin chains with a nearest-neighbour interaction and fermionic quantum oscillator models.

An important stage in the study of the generalized "internal" symmetry of quantum field theory models in space-time dimension D=2 is completed. Some of the models of this type describe realistic and potentially interesting physical configurations. The relevant symmetries (of quantum group type) and the statistics related to them (braid instead of permutation group) provide much richer diversity than their counterparts common for D>3.

It is shown that the generalized Euler characteristics of minimal free resolvents of the Fock spaces of the parastatistics algebra osp(2m+1|2n) provides Schur polynomial identities. The hypothesis that the diagonal subalgebra $D_q(n)$ of the algebra of regular functions on the quantum group $GL_q(n)$ is a cubic algebra is proved for low dimensions (n<5) which is a substantial progress with respect to the existing result of Lascoux for n=2. The relation to the Poirier-Reutenauer algebra is also found.

Superconformal vertex operators, i.e. fields on the superspace together with a state-field correspondence, are constructed in a canonical way for vertex algebras with extended superconformal symmetry leading to the notion of superconformal vertex algebras in D=4.

Area 2: Conformal and Superconformal Symmetry in Gauge, Field and String Theory (*V.K. Dobrev, V.B. Petkova, L.K. Anguelova, M. Stanishkov, S. Stoimenov, S.G. Mikhov, O. Stoychev,*)

(2a) Strongly-interacting gauge fields (*L.Anguelova*) We continued the study of gauge theories with dynamically broken chiral symmetry. We developed a general method for the study of instabilities in such theories. We investigated the phenomenologically important example of holographic model with dynamically impaired chiral symmetry, which develops perturbative instability. We also made significant progress in developing a new type of inflationary cosmology models based on strongly interacting gauge fields.

(2b) Conformal and Superconformal Symmetry in Field and String Theory (*V.Petkova, M. Stanishkov, O. Stoychev*)

In work in progress a class of multiple integrals representing 3-point functions in conformal *sl (4)* Toda theory is calculated and the result is analytically continued beyond the range of validity of the Coulomb representation. The idea is to use these constants in the system of equations derived from the condition of locality of the related 4-point functions, for a calculation of the matrix elements of one of the fundamental braiding matrices in the theory with possible application to problems in the gauge-gravity correspondence.

We extend the results on the RG flow in the next to leading order to the case of the super-symmetric minimal models SM_p parametrized by integer p in the case p>> 1. We explain how to compute the Neveu-Schwarz and Ramond conformal blocks in the leading order in 1/p following the renormalization scheme proposed earlier. We obtained the anomalous dimensions of certain NS and Ramond fields. It turns out that the linear combination expressing the infrared limit of these fields in term of the IR theory SM_{p-2} is exactly the same as those of the nonsupersymmetric minimal theory.

(2c) Invariant (Deformed) Differential Equations and Non-Standard Quantum Groups (*V. Dobrev, S. Stoimenov, S. Mikhov*) Continuing work on the AdS/CFT correspondence for the AdS group SO (3,2) we constructed the intertwining operators: boundary-to-bulk and bulk-to-boundary, for arbitrary integer spin. We continued the work on the construction of differential operators for various noncompact semisimple Lie groups. We made the multiplet classification of special multiplets of the pseudo-orthogonal group SO (p, q) determining the parameters for all classified invariant differential operators. Classified are also the so-called minimal representations. We made the multiplet classification of special multiplets of the pseudo-unitary group SU (4,4).

Another task was to investigate the algebra of symmetries of the Boltzmann transport equation (BTE). Since the function of the particle distribution depends on time, space and speed, also the corresponding algebra was sought in terms of these variables, which is an innovative and non-trivial task. Our preliminary results show that at least for a particular form of BTE we have found a representation of the conformal algebra. Further generalizations will give symmetry algebras of more general forms of BTE.

Area 3: New Aspects in String Theory and Gravitation (*E. Nissimov, S. Pacheva, B. Ivanov, P. Bozhilov, D. Doneva, D. Staicova, B. Damyanov*)

(3a) ***Generalized Gravity and Nonlinear Gauge Theories with Applications to Elementary Particle Physics and Cosmology*** (E. Nissimov. S. Pacheva)

Employing alternative spacetime volume-forms (generally-covariant integration measure densities) independent on the pertinent Riemannian spacetime metric have profound impact in general relativity. Although formally appearing as "pure-gauge" dynamical degrees of freedom they trigger a number of remarkable physically important phenomena, among the principal ones : (i) new mechanism of dynamical generation of cosmological constant; (ii) new mechanism of dynamical spontaneous breakdown of supersymmetry in supergravity - simultaneous generation of a small observable cosmological constant and a very large gravitino mass; (iii) new type of "quintessential inflation" scenario in cosmology - generation of a remarkable effective scalar potential with two infinitely large flat regions capable to describe both the early as well as the late universe; (iv) gravitational electrovacuum "bags", partially resembling the features of MIT bags and constituent quark models in QCD.

(3b) ***Gauge/gravity duality and integrability in string theory relevant for the Anti-de-Sitter/conformal-field-theory correspondence*** (P. Bozhilov). We develop an approach for solving the string equations of motion and Virasoro constraints in any background which has some (unfixed) number of commuting Killing vector fields. We consider strings moving in the eta-deformed AdS_5 x S^5 and obtain a class of solutions depending on several parameters. We derive the 3-point correlation function between two giant magnons heavy string states and the light dilaton operator with zero momentum in the eta-deformed AdS_5 x S^5.

(3c) ***Relativistic gravity and astrophysics – exact solutions of Einstein's equations*** (B. Ivanov). An investigation of collapsing spheres of anisotropic fluids with heat flow, representing models of collapsing and radiating stars in astrophysics, has been initiated. The collapse of anisotropic fluid spheres towards black holes or naked singularities and Minkowski spacetime has been studied in the most general situation – when there is shear, expansion and acceleration and the metric has 3 different components, functions of time and distance from the centre of the sphere. Different solutions have been found.

(3d) ***Models and dynamics of rapidly rotating neutron stars*** (D. Doneva). We study neutron star models, both static and rapidly rotating, in Einstein's theory of gravity and its generalizations, such as scalar-tensor theories and f(R) theories of gravity. The results show that rapid rotation can significantly magnify the deviations from general relativity which offers a new window towards exploring the alternative theories of gravity. The astrophysical implications of the neutron star models are also investigated in detail, such as the universal I-Q relations, the quasiperiodic oscillations and the emission of gravitational waves by oscillating neutron stars. The aim is to study the different manifestations of generalized theories of gravity at astrophysical scales and to explore the possibility to test these theories via observations.

(3e) ***Electromagnetic spectra of the Kerr black hole*** (D. Staicova). We continue the study of the quasinormal modes -- complex frequencies describing the perturbation of the Kerr metric in late times, which is an important subject due to its relevance to the physics of the gravitational waves.

(3f) ***Applications of generalized functions of Colombeau for modeling of singularities*** (B. Damyanov). Modeling of singularities given by distributions or discontinuous functions by means of the generalized functions of Colombeau has proved useful in many physical problems such as geodesics for impulsive gravitational waves, jump conditions in hyperbolic systems and others. Methods based on algebra of generalized Colombeau functions are applied to obtain results for singular products of Schwartz distributions.

Area 4: Theory and Phenomenology of Elementary Particles and Their Bound States (*E. Christova, D. Bakalov, D. Stamenov, M. Stoilov, B. Obreshkov, E. Ginina*)

Partonic spin content of the nucleon and QCD (E. Christova, D. Stamenov)

The fact that analyses of *semi-inclusive* deep inelastic lepton-nucleon scattering (SIDIS) $l+N \to l+h+X$, where h is any final hadron, suggest that the polarized strange quark density $\Delta s(x)$ is positive in the measured region of Bjorken x, whereas all analyses of *inclusive* deep inelastic scattering (DIS) $l+N \to l+X$ yield significantly negative values of this quantity, is known as the ``strange quark polarization puzzle". Our new analysis of the inclusive world data (D. Stamenov in a collaboration with E. Leader, Imperial College, London and A. Sidorov, JINR, Dubna), including for the first time the extremely accurate JLab CLAS data on the proton and deuteron spin structure functions, allowing in the parametrization for a possible sign change, has confirmed the previous claim that the inclusive data yield significantly negative values for $\Delta s(x)$. The fundamental difference between the SIDIS and DIS analysis is the necessity in SIDIS to use fragmentation functions (FFs), which are largely determined from multiplicity measurements. It is known that the polarized strange quark density extracted from SIDIS data is extremely sensitive to the input kaon fragmentation functions. Thus we believe that the present disagreement between the SIDIS and DIS strange quark polarizations very likely results from a lack of correct information on the fragmentation functions, and the results from inclusive analysis are correct.

Now it is clear that the collinear approach to the hadron structure, at which the quark momenta and spin are assumed parallel to the nucleon momenta and spin, is too naïve and the transverse quark momentum has to be taken into account. This implies that parton densities (PDFs) and FFs are more complicated objects in which transverse-momentum dependence (TMD) has to be included. Their extraction from experiment requires more complicated and precision measurements. We generalize the model independent approach, developed previously and applied usefully to the collinear case, to the non-collinear case and obtain expressions for the valence-quark TMD-PDFs and TMD-FFs in terms of the measured multiplicities in unpolarized SIDIS without any contributions from the poorly known sea-quark densities. Such measurements are performed in JLab, COMPASS (CERN) and HERMESS (DESY).

LABORATORY: MATHEMATICAL MODELLING

HEAD OF LABORATORY: PROF. DSC DIMITAR BAKALOV

In 2014 researchers from the Laboratory have been working on bilateral collaboration projects with INFN (Italy), UPS "Paul Sabatier" (Toulouse, France), JINR-Dubna (Russia), IFJ (Krakow, Poland) etc. The main research activities in the Laboratory were focused on the following topics:

Modelling of experimental data

Original mathematical methods and algorithms, based on the theory of orthonormal polynomials, and FORTRAN language implementations have been applied to investigations in the field of biotechnology, atmospheric physics and ecology [Lett. PEPAN, 11, p.69 (2014)].

Physics of exotic atoms.

As part of the preparation of the experiment for the measurement of the hyperfine splitting in muonic hydrogen and the determination of the Zemach radius of the proton, detailed Monte Carlo simulations of the apparatus for the preliminary experiment at the muon facility of RAL-RIKEN (UK) aimed to measure the temperature dependence of the muon transfer rate have been performed, a mathematical model of the measurement has been developed and the optimal geometrical and physical parameters have been investigated. [Phys. Lett. A 379, (2015) 151; Hyperfine Interact. DOI 10.1007/s10751-015-1148-6].

In parallel, the work on the systematic density effects in antiprotonic helium spectroscopy was extended to solid helium targets, that offer unique opportunities for the study of helium structure [Phys. Rev. A 90, 054501 (2014)].

Precision molecular spectroscopy

The high precision spectroscopy of the molecular ion HD^+ open perspectives for the very accurate determination of some fundamental physical constants and their variability in time by comparison of experimental data to accurate theoretical calculations of the spectra. In a series of papers the most important systematic effects including the Stark shift and the black-body radiation shift were evaluated with high accuracy [Appl.Phys.B114, 213 (2014), Phys. Rev. A89, 052521 (2014)] and a new, more precise molecular clock was proposed based on composite frequency spectroscopy in HD^+ [Phys. Rev. Lett. 023004 (2014)]. The latter was selected as a highlight by the PRL editors.

Low-energy atomic processes.

In the theory of interactions of atoms with surfaces, the streaking of electrons emitted from metal surfaces was investigated [Proceedings of the 33rd International Workshop on Nuclear Theory, Nuclear Theory, Vol. 33 (2014)].

Quantum field theory

New results have been achieved on the renormalization group flow in two-dimensional superconformal models [Nucl.Phys. B885 (2014) 713] and in theory of quantization [Proceedings of the X International Workshop „Lie Theory and Its Applications in Physics, Vol. 111].

LABORATORY: THEORETICAL NUCLEAR PHYSICS

HEAD OF LABORATORY: ASSOC. PROF. DR MITKO GAIDAROV

In 2014 the members of the Nuclear Theory Laboratory (NTL) of the Institute for Nuclear Research and Nuclear Energy (INRNE) continued the investigations on the scientific project "Theory of the atomic nuclei and other many-fermion systems". They authored 22 scientific works, from which 19 published and 3 pending papers in international journals and conference series, within a broad international collaboration. In 2014 scientific papers of Laboratory's members had 108 independent citations in international scientific journals and conference proceedings world-wide. The main scientific results of NTL obtained during 2014 acording to the topical research plan of INRNE are listed below.

1. Theory of nuclear structure and nuclear reactions (Assoc. Prof. Dr. Mitko Gaidarov, Assoc. Prof. Dr Dimitre Kadrev (principal investigators), Prof. DSc Sevdalina Dimitrova, Assoc. Prof. Dr Martin Ivanov, Prof. DSc Anton N. Antonov (Associated Member of INRNE), Dr Korneliya Spasova (Assoc. Prof. in Shumen University))

Charge-current quasielastic (anti)neutrino scattering cross sections on a ^{12}C target are analyzed using a spectral function that gives a scaling function in accordance with the (e,e') scattering data. The spectral function accounts for the nucleon-nucleon correlations, it has a realistic energy dependence, and natural orbitals from the Jastrow correlation method are used in its construction. The calculations based on the impulse approximation underpredict the MiniBooNE data but agree with the data from the NOMAD experiment. A comparison of the theoretically obtained in two different nuclear models results with the recent data for the corresponding observables published by the MINERνA Collaboration is made.

A comprehensive study of various ground-state properties of neutron-rich and neutron-deficient Mg isotopes with A=20-36 is performed in the framework of the self-consistent deformed Skyrme-Hartree-Fock plus BCS method. The results of the calculations show that the behavior of the nuclear charge radii and the nuclear symmetry energy in the Mg isotopic chain is closely related to the nuclear deformation. We also study, within our theoretical scheme, the emergence of an "island of inversion" at the neutron-rich ^{32}Mg nucleus, which was recently proposed from the analyses of spectroscopic measurements of the ^{32}Mg low-lying energy spectrum and the charge rms radii of all magnesium isotopes in the *sd* shell.

The density distributions of ^{10}Be and ^{11}Be nuclei obtained within the quantum Monte Carlo model and the generator coordinate method are used to calculate the microscopic optical potentials (OP's) and cross sections of elastic scattering of these nuclei on protons and ^{12}C at energies $E<100$ MeV/nucleon. The real part of the OP is calculated using the folding model with the exchange terms included, while the imaginary part is obtained in the high-energy approximation. In this hybrid model of OP the free parameters are the depths of the real and imaginary parts obtained by fitting the experimental data. The well-known energy dependence of the volume integrals is used as a physical constraint to resolve the ambiguities of the parameter values. The role of the spin-orbit potential and the surface contribution to the OP is studied for an adequate description of available experimental elastic scattering cross-section data.

Pre-equilibrium proton-induced α-particle emission at incident energy from 65 up to 160 MeV were investigated with polarized projectiles. A formalism based on the statistical multistep direct emission model of Feshbach, Kerman, and Koonin and the distorted-wave Born approximation to calculate the double-differential cross sections and analyzing powers was used. The optical model potentials employed for the interactions between the projectile and target, and between the ejectile and the heavy residual nucleus are obtained within a hybrid model. It is shown that the reaction mechanism (knockout or pickup processes) strongly depends on the incident energy.

2. Models of complex deformed nuclei, symmetries and fine structure of nuclear spectra (Assoc. Prof. Dr. Nikolay Minkov (principal investigator), Assoc. Prof. Dr. Svetla Drenska, Assist. Prof. Dr Plamen Yotov, Dr. Kalin Drumev)

We have shown that the potential in the radial equation in the model of coherent quadrupole-octupole motion (CQOM) in nuclei generates a sequence of super-potentials and subsequent series of effective potentials which satisfy the shape-invariance condition and correspond to a SUSY-QM hierarchy of Hamiltonians. On this basis we suggested that the CQOM level scheme possesses a generic supersymmetric structure. We outlined the mechanism in which the quadrupole-octupole (QO) spectra in even-even and odd-even nuclei deviate from the genuine symmetry. We illustrated the possibilities to identify the signs of supersymmetry in QO spectra described within the CQOM approach. We studied the influence of the QO deformations on the energy and magnetic properties of high-K isomeric states in even-even heavy and superheavy nuclei within a deformed shell model with pairing interaction. The calculations outlined three groups of nuclei: with pronounced, shallow and missing isomer-energy minima with respect to the octupole deformation. The result indicates regions of nuclei with octupole softness as well as with possible octupole deformation in the high-K isomeric states. These findings show the need of further theoretical analysis as well as of detailed experimental measurements of magnetic moments in heavy deformed nuclei.

The algebraic realization of the Pairing-plus-Quadrupole Model in the framework of the Elliott`s SU(3) Model was explored with the aim to obtain the complementary and competing features of the two interactions through the relation between the pairing and the SU(3) bases. Some particular examples based on this SO(8)-SU(3) basis correspondence were applied for the build-up of a more elaborated microscopic shell model that can be used in a realistic nuclear system description.

3. <u>Structure and dynamics of many-fermion systems</u> (Assist. Prof. Dr Rossen Pavlov (principal investigator), Assist. Chavdar Velchev, Assist. Prof. Dr Lubomir Mihailov (ISSP), physicist Maria Dimitrova-Ivanovich, PhD student Yuliya Mutafchieva, PhD student Zhivko Stoyanov)

A study of the outer crust structure of cold non-accreting neutron stars in the presence of a strong magnetic field, when taking into account the quantization of the particles in this field, was conducted. The research also included the study of the structure of the neutron star inner layers in a continuous interval for the pressure and the magnetic field values when taking into account the temperature dependencies.

The effects of very strong magnetic fields on the solid crust of neutron stars were studied. The matter in this crust is composed of fully ionized atoms and the electron velocity is close to the speed of light. The composition of this dense matter was determined, as a function of the density and the magnetic field, using the latest tables for atomic masses obtained in collaboration with a research team from the Free University of Brussels. It was also demonstrated that the quantization of electron motion in a magnetic field (Landau quantization) leads to important modifications of the structure and properties of the neutron star crust. The magnetic field imposes the massive increase in the density and thickness of the surface layer of the star. This phenomenon of magnetic condensation is explained using a simple model by obtaining analytical form of the equation of state as a function of the density. The effects of very strong magnetic fields in the inner layers of neutron stars will also be studied next.

The research on heliumoid electron-nuclear systems continued in 2014 and the studies also included heliumoid meson-nuclear systems. Methods for calculating the quantum characteristics of the electron ground state of heliumoid electron-nuclear systems were developed. The obtained results are the most precise in the available literature. For the nuclei masses was used recently obtained experimental data for 3500 nuclei complemented with nuclei masses calculated with optimized versions of the Hartree-Fock-Bogoliubov method. Staggering effects between the masses of the nuclei and electron energy characteristics were studied and new correlations between the ground state energy characteristics and the nuclear proton and neutron magic numbers were established. These results provide possibilities to determine and verify new neutron magic numbers when the number of neutrons is large and to study the effects induced by the deformation of the nuclei on the electron structure. The high accuracy of the results enables their use in precision approaches for analysis of low-density high-temperature astrophysical (in the solar corona) and laboratory (controlled fusion, tokamak) plasma.

The ground state energy characteristics of heliumoid meson-nuclear systems were analysed. The aforementioned methods or the determination of the energy characteristics of heliumoid electron-nuclear systems were used. Considering the results for electron-nuclear systems, implementing these methods for meson-nuclear systems is also expected to generate high-accuracy results. The difference in the radii of the electron and meson systems predicts a greater sensitivity of the meson-nuclear systems to Coulomb field spherical symmetry deviations which can be applied for learning the parameters of the nuclei.

LABORATORY: <u>SOLITONS, COHERENCE AND GEOMETRY</u>

HEAD: PROF. DSC VLADIMIR GERDJIKOV

The main research topics of the Laboratory are soliton theory, differential geometry and gravitation, and coherent states and quantum physics. The Laboratory supports collaborations with the Department of physics of the University of Salerno, Salerno, Italy, Applied Math. Department, University of Leeds,UK, Dublin Institute of Technology, Dublin, Ireland, Department of applied mathematics, Univesity of Central Florida, Florida, USA, Faculty of applied mathematics and informatics of the Technical University, Sofia, Bogolyubov Laboratory of Theoretical Physics of the Joint Institute for Nuclear Research, Dubna, Russia, National Institute for Nuclear Research and Nuclear Engineering in Bucharest, Romania, the Department of Physics, University of Craiova, Romania, the Faculty of Physics, Sofia University.

The Laboratory is supporting the activity of the South-East European Network in Mathematical Physics SEENET MTP whose Bulgarian participation is coordinated by prof. B.Aneva. Members of the laboratory used the Net and took part in two International Conferences in Romania. A joint research work with the University of Craiova continued and as a result Ms. Corina Babalic, a Romanian PhD student at Craiova University defended successfully her PhD thesis "Sisteme neliniare integrabile şi fenomenologie solitonică". A follow-up activity was the mobility program with visits of Bulgarian participants in the project to the University of Nis, the Technical University of Istanbul and the University Ss Cyril and Methodius of Skopje.

Traditionally our scientific results during 2014 were in four directions:

I. Soliton theory, Integrable systems and applications (V.S. Gerdjikov, M. Todorov, A. V. Mikhailov, G. G. Grahovski, R. Ivanov, T. I. Valtchev, A. Kyuldjiev) with two subtopics:

A. Integrable multicomponent nonlinear evolution equations; B. N-soliton interactions

II. Differential Geometry and Local interactions of physical fields (B. Dimitrov, M.Tashkova, S.Donev,)

III. Coherent states and Quantun Physics (D. Trifonov, A. Angelow, V. Angelov, O. Cherbal)

IV. Mathematical methods of many-body systems and generalized quantization methods (B. Aneva)

V. Organizational and Publication activities.

In 2014 members of the Laboratory took part in organizing the 16-th international conference **Geometry, Integrability and Quantization,** Varna, June 6--11, 2014.

The publication activity of the Laboratory included:

- The Proceedings of the International conference 'Integrability, Recursion Operators and Soliton Interactions' were published as a special volume of Avangard Prime Editorial house, Eds.: B. Aneva, G. Grahovski, R. Ivanov and D. Mladenov.
- The Proceedings of the International School and Workshop on Nonlinear Mathematical Physics and Natural Hazards, held in Sofia in .2013 were published as volume 163 of the series Springer Proceedings in Physics, Eds. B. Aneva and M. Kuteva-Guentcheva.

- 12 articles in journals, 6 reports in proceedings of International conferences and Proceedings of two conferences.
- Members of the Laboratory have participated in 13 international conferences and presented 19 reports.

In 2014 Prof.DSc Boyka Aneva had two lecture courses on supersymmetries and on stochastic processes at the PhD School of the Bulgarian Academy of Sciences. Two PhD students have successfully passed the exams on these subjects.

HIGH ENERGY PHYSICS AND PARTICLE and ASTROPARTICLE PHYSICS

LABORATORY: HIGH ENERGY

HEAD OF LABORATORY: ASSOC. PROF. DR GEORGI SULTANOV

The principal area of activities of the physicists from the High Energy Physics Laboratory is in the CMS experiment at LHC, CERN. Our work in CMS is supported by a contract with the Bulgarian National Science Fund.

During the 2013-2015 shutdown of LHC, the CMS experiment undergone several important upgrades. A major one was the extension of the muon detector system. In 2014 we continued to participate in the work on the upgrade of the RPC system, which involved construction and installation of two new layers, located in both endcap regions of the CMS detector. 144 double-gap RPC-chambers, grouped into 72 super-modules, were used for construction of two new detector stations. After installing in 2013 a new RPC station at +z endcap region, in 2014 second new RPC station at -z endcap region was installed. Members of our laboratory took active part in the work at CERN on RPC chamber and super-module assembly, their functional testing with cosmic muons and subsequent installation in the CMS experiment.

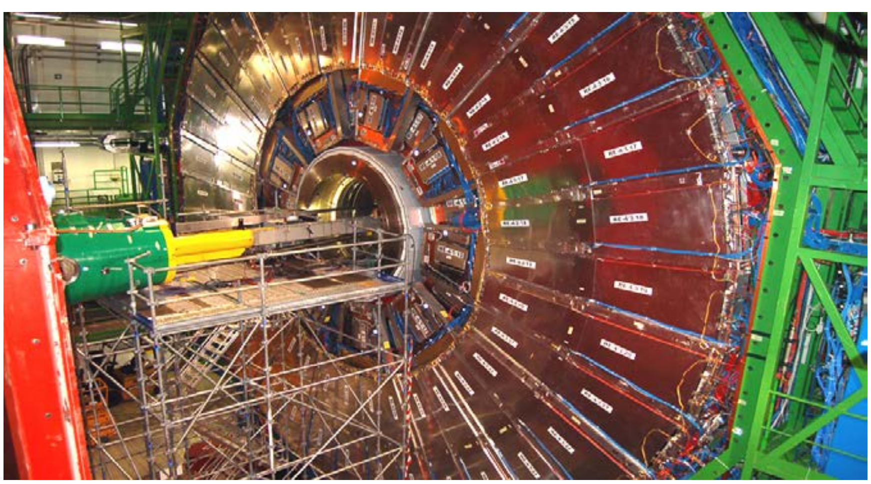


Figure 1: The -z endcap of the CMS experiment with installed new 4-th RPC station.

We also took part in the R&D work on the new muon detectors that use gas electron multiplier (GEM) technology. A set of such chambers, denoted as GE1/1, is planned to be installed in the CMS forward regions as a preparation for work under the conditions of the future high-luminosity upgrade of LHC. We participated in the work on the TDR that describes the GE1/1 project, contributing to Monte-Carlo studies for background evaluation and modeling the high luminosity environment.

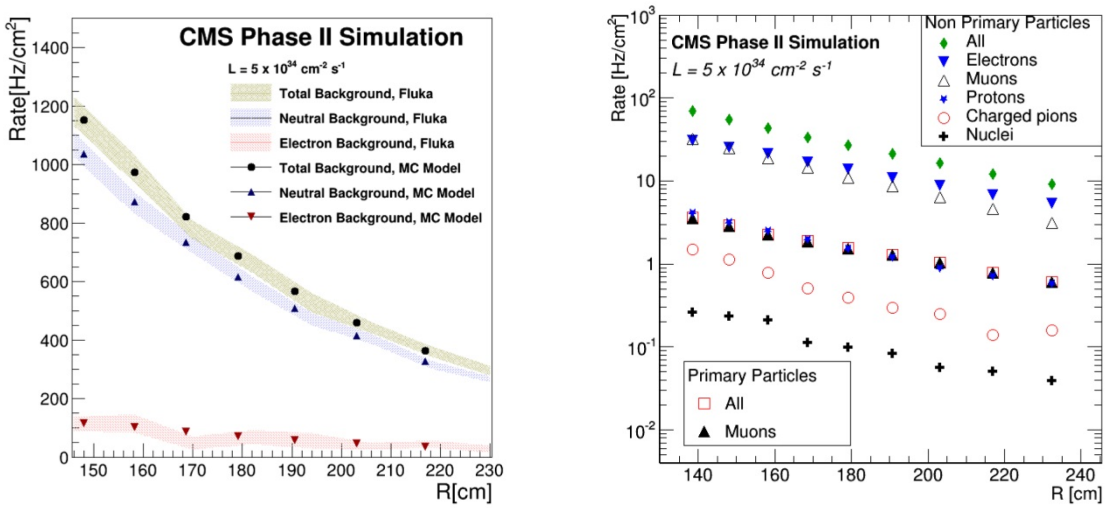


Figure2: (Left): The GE1/1 hit rate due to neutron-induced backgrounds. (Right): Rates of prompt particles as a function of the radial distance to the beam pipe.

Our INRNE group also took responsibility for the design and prototype production of GE1/1 chamber cooling system.

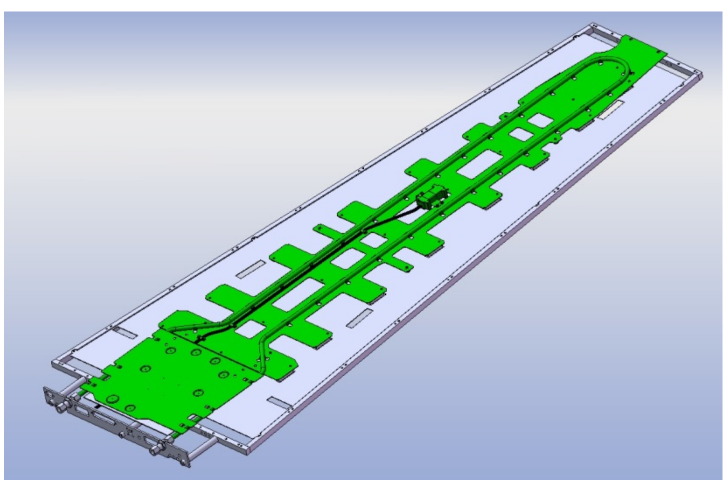


Figure3: Top view of the GE1/1 on-detector cooling design.

In 2014 we participated in finalizing the analysis of the search of vector-like quarks, T and Q, that are pair-produced in pp interactions at $\sqrt{s}$ = 8 TeV and decay exclusively to bW or qW. Pair production of T/Q quarks is excluded at 95% CL for masses below 912 GeV for T and 788 GeV for Q. This represents the first result obtained for Q-quarks and the most restrictive limit for T-quarks.

LABORATORY: PARTICLE AND ASTROPARTICLE PHYSICS

HEAD OF LABORATORY: ASSOC. PROF. DR PETAR TEMNIKOV

The staff of the Laboratory is involved in some of the most prominent experiments in Particle astrophysics and High energy physics - MAGIC and CTA in gamma-ray astrophysics, ATLAS and NA49 in CERN.

Magic experiment

In 2014 the results of MAGIC collaboration were published in 16 articles in Astronomy and Astrophysics, Astrophysical Journal and Science. Another 3 articles were accepted for publication and 4 articles were sent for publication.

One of the most interesting results is connected with the detection of very rapid variation of gamma-ray luminosity from the super massive black hole in the galactic IC310. The observed variation time of 5 minutes corresponds to the size of the emission region smaller than 20% of the gravitational radius of the central black hole. This phenomenon in combination with simultaneously obtained radio emission from the same source, requires total revision of the existing models of relativistic jet formation close to the black holes. This result is published in SCIENCE journal.

Another very interseting discovery of MAGIC experiment is the observation of the most distant object S3 0218+357 emitting gamma-quanta with energies > 100 GeV, detected till now. The observations of the faint signal (redshift 0.944+/-0.002) was possible due to the fact that there exists another galaxy realizing gravitational lensing on the way of gamma-rays to the Earth. This detection was performed with the direct activity in situ of our colleague V. Verguilov.

In 2014 four other sources were discovered of very high energy gamma quanta: BL Lac objects RX J1136.5+6737 and 1ES 1727+502, blasar 1ES 0033+595, pulsar wind nebulae 3C 58.

Many known objects were investigated in details and observed simultaneously in multiwave observational campaigns in cooperation with other experiments in different wave ranges of electromagnetic spectrum: radio, optical, X-rays and low-energy gamma-rays.

The staff of the laboratory is concentrated on the development of different multivariate statistical methods for physical analysis of the detected astrophysical data.

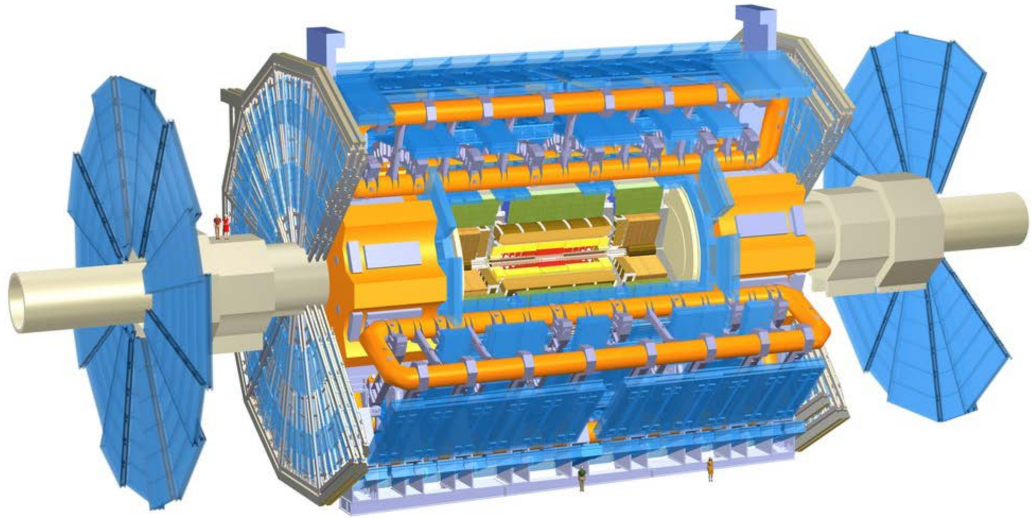
We participate in the preparation of the next generation of Cherenkov gamma experiment CTA. At the moment it includes more than 1000 scientists from 30 countries all over the world.

CTA concept

CTA - Central part

A member of our staff M.Makariev takes part of NA49 CERN experiment. The experiment collected huge amount of data about prton-nucleus and nuccleus-nucleus collisons at energies between 20 and 158 GeV per nucleon. In 2014 two articles were published with leading role of our colleague.

M. Shiyakova is a member of Distributed Analysis Shifters Team, responsible for GRID calculation of ATLAS (CERN) experiment. She is also a Shift Lesder on the Matter of Safety. She takes part of ATLAS experiment via INRNE-JIRN (Dubna) cooperation.



ATLAS experiment

NUCLEAR PHYSICS

LABORATORY: NUCLEAR SPECTROSCOPY

HEAD OF LABORATORY: CORRESPONDING MEMBER OF BAS,

PROF. DSC CHAVDAR STOYANOV

During 2014 the activity of Laboratory of Nuclear Spectroscopy was concentrated on the traditional for the Lab fields – theoretical, experimental nuclear physics, accelerators and applications connected with the research topic “Nuclear Structure and Applications”.

- **Project “Energy & Transmutation” collaboration with Joint Institute for Nuclear Reserch - Dubna**

During last fifty years the various types of ADS have been studied in Dubna experimentally and theoretically. There were studied ADS with natural and depleted uranium targets, lead-uranium and lead-graphite target assemblies irradiated by protons or deuteron beams with energy from 0.66 to 3.7 GeV. A lot of valuable information was obtained. Last four years the new project “Energy and Transmutation Radioactive Wastes” (E&T RAW) was launched at JINR . In the framework of this project during 2011 -2014 a wide variety of experiments have been done using massive (512 kg) natural uranium target assembly (TA) QUINTA irradiated by deuteron beams of JINR Nuclotron in incident energy range (1 – 8) GeV. TA QUINTA has target of hexagonal shape about 30 cm in diameter and 65 cm in length surrounded by a lead blanket of thickness 10 cm.

The neutron spectrum was measured with threshold activation detectors located inside of TA as well as on the surface of the lead blanket. The rates of reactions (n,f), (n, ^{nat}U and other samples were measured. The experimental results were (n,2n) compared with the calculations made with the different codes (MCNPX, Fluka, MARS, GEANT4) which used various nuclear models (ISABEL, INCL4, LAQGSM, Bertini and fission evaporation model ABLA). The overall agreement in limits of (10 – 30) % between the experiment and calculations for spatial distribution and integral values of ^{nat}U(n,f), (n, - reaction and (n,2n) rates was achieved. These reactions are determined mainly with the part of the neutron spectrum energy below 20 MeV. But for ^{209}Bi(n,f)-reaction and production of ^{7}Be and ^{22}Na nuclei in aluminum foils which is connected with high energy (E_n > 30 MeV) part of the neutron spectrum a discrepancy between experiment and calculations exceeds 100%. This means that present codes are not able to reproduce high energy tale of neutron spectrum formed within natural uranium target of intermediate size such as TA QUINTA.

During the analysis of the experimental results some semi- phenomenological estimates were made of the impact of high-energy part of the neutron spectrum (E_n > 20 MeV) on integral numbers of fissions N_f for TA QUINTA and available at JINR quasi-infinite (with small neutron leakage) Big URANium (BURAN) TA of depleted uranium mass of about 21t. Calculations have shown that, if for the TA QUINTA with a large (~ 80%) neutron leakage the effect of ~ 30%, so for the quasi-infinite target the correct account of the role of high-energy neutrons can lead to an increase in N_f at ~100%.

- **Development of microscopical models for the description of the atomic nuclei:**

The collective excitations in nuclei gives insight into the mechanisms responsible for driving these strongly interacting many-body systems toward deformation. Highly correlated collective structures originate from a coherence in the independent motion of the neutrons and protons in a mean field modified by the residual interactions between the nucleons. Investigations of isoscalar and isovector excitations in a chain of isotopes provide extensive complementary information on the proton–neutron interaction. Often, the under lyings single-particle structure has been found to influence the stability of such collective excitations, showing an interesting interplay between collective and the single-particle degrees of freedom. This competition results in an evolution of nuclear properties with *N* and *Z*, as well as with excitation energy and angular momentum.

In recent studies along the *N*=80 ^{134}Xe, ^{136}Ba and ^{138}Ce isotones, a large impact of the single-particle structure on collective mixed-symmetry states (MSSs) was observed. In the frame work of the interacting boson model-2, MSSs are described as excitations in which protons and neutrons move partially out of phase. Their fully-symmetric analog states (FSSs), i.e., 2^+_1states in even–even nuclei, where the two types of nucleons move in phase, have similar configurations and are lower in excitation energy. A characteristic property of MSSs is their connection to FSSs with the same number of quadrupole bosons via strong M1 transitions.

In ^{138} Ce, the M1 transition strength between the higher-lying (2+1,*ms*) mixed-symmetry level and the first excited 2^+ state was found to be fragmented. In contrast, in 134Xe and 136Ba the M1 strength remains largely concentrated in a single transition. Moreover, the total measured M1 strength is smaller for ^{138}Ce than for the other isotones. These observations were attributed to a lack of shell stabilization in ^{138}Ce, based on calculations within the quasiparticle–phonon-model (QPM). In this concept, the purity of the $2^+_{1,ms}$ state gets “washed out” in^{138}Ce due to its single-particle structure. In a simplified independent-particle model, the complete filling of the $\pi g_{7/2}$ orbital at Z=58 leads to configurations involving the higher-lying $\pi d_{5/2}$ orbital for the FS and MS one-phonon 2^+ states. Multi-phonon 2^+ states have similar proton configurations. Hence, mixing of the one-phonon MSS with nearby, higher-seniority 2^+ states can occur in ^{138}Ce, in contrast to^{134}Xe and ^{136}Ba, where the $\pi g_{7/2}$ orbital is not fully occupied and the $2^+_{1,ms}$ state remains rather pure. Extending the shell stabilization concept to^{140}Nd, one would expect a similar fragmentation of M1 strength as in ^{138}Ce. However, although both $2^+_{3,4}\rightarrow 2^+_1$ decay shave dominant M1 character, only the absolute B(M1;$2^+_4\rightarrow 2^+_1$) strength has been measured, and no final conclusion can be drawn at this point.

The g factors calculated within the QPM drop toward Z=58, in accordance with a decreasing importance of proton contributions to the 2^+_1 wave function, in the presence of a $\pi g_{7/2}$ subshell closure. Data up to Z=56 suggest rather constant $g(2^+_1)$ factors, in fair agreement with the QPM.The result at Z=58 does support a drop, however, a near-constant behaviour cannot be ruled out in view of the uncertainty for the measured value. A constant trend of the $g(2^+_1)$ factors would be expected for rather pure $\pi g_{2\sigma 7/2}$ (σ=1,2,3) configurations, until Z=58 is reached. Similarly, the experimental B(E2)↓values are reproduced well by QPM for Z<60.

The isoscalar dipole strength distribution in nuclei contributes to the Schiff moment. The nuclear Schiff moment is essential in the mechanism that induces parity and time-reversal violations in the atom. The properties and systematics of the isoscalar dipole in nuclei with an emphasis on the low-energy strength and the inverse energy-weighted sum which determines the Schiff moment are explored, theoretically. We also study the influence of the isovector dipole strength distribution on the Schiff moment. The influence of large neutron excess in exotic nuclei is examined. The centroid energies of the isoscalar giant dipole resonance and the overtone of the isovector giant dipole resonance are given for a wide range of nuclei.

The question of how to improve the agreement between theoretical nuclear single-particle energies (SPEs) and observations is studied. Empirically, in doubly magic nuclei, the SPEs can be deduced from spectroscopic properties of odd nuclei that have one more or one less neutron or proton. Theoretically, bare SPEs, before being confronted with observations, must be corrected for the effects of the particle vibration coupling (PVC). The PVC corrections are determined in a fully self-consistent way. Then, the SPEs is adjusted, with PVC corrections included, to empirical data. In this way, the agreement with observations, on average, improves; nevertheless, large discrepancies still remain. The conclusion is that the main source of disagreement is still in the underlying mean fields, and not in including or neglecting the PVC corrections.

- **Beam dynamics studies in the framework of the photo-injector PITZ, DESY Zeuthen**

In terms of the collaboration between INRNE and PITZ in DESY in 2014 the conditioning of an RF gun is studied. Additionally, an RF gun conditioned in 2013 has been characterized as my activities are related to measurements of the transverse phase space using the standard slit scans and tomography diagnostics as well. In string 2014 the conditioning of a T-combiner is studied, together with two RF windows.

Concerning the topic started in 2013 – preparation of the PITZ electron beam for beam driven plasma wakefield acceleration, a new set of numerical simulations, defining the parameters of a third harmonic cavity used for linearization of the longitudinal phase space is finished. Changes in the parameters defined beforehand were necessary since the booster cavity position was modified due to requirements of the plasma chamber installed behind the booster. Another task was started – modification of the sub-bunch charge in order to mitigate the smearing of the current profile during acceleration with the gun cavity. A new set of numerical simulations was started with the goal of design of a magnetic chicane in front of the plasma chamber. Part of the work done for PITZ was reported on the annual spring meeting of Deutsche Physikalische Gesellschaft in Dresden and the annual NICA workshop in Sozopol. Part of the simulation results has been transmitted to a theory group, calculating the beam dynamics in the plasma. The goal is to define the pulse parameters critical for reaching maximal possible transformer ratio.

- **Accelerator**

During 2014 the work on the heavy ion accelerator complex NICA, under construction at JINR-Dubna, continues with modernization of the superconducting synchrotron Nuclotron accelerating system. A mode of operation of Nuclotron RF system with simultaneous extraction of two ion beams with different energies was realized. This allows for concurent work of the accelerator with two experiments. Dynamic aperture study of the superconducting collider also started. Beam particles were tracked for one million turns by means of MADX and SIXTRACK codes, with the collider structure using the measured fields of the dipoles, including systematic and random errors. Derived results show that transversal sizes of the beam are much smaller than dynamic aperture assuring long-term stability of the collider beams.

Under collaboration with the LPSC- Grenoble on the design of a positrons source with low energy it was further developed theoretical model, which will considerably facilitate the optimization of the source. On the basis of the model are made the first simulation.

Expert assistance for the project of a cyclotron centre in INRNE was done.

- **Applications:**

1. Radionuclide and element analysis of uranium minerals and ores from different origins

Several samples of uranium minerals and ores from Tanzania, Africa have been investigated using High Resolution Gamma-Ray and Energy Dispersive X-Ray spectroscopy. The concentrations of natural uranium and certain associated elements have been estimated. These data are important for geochemical fingerprinting of relatively strong natural radioactive (NORM) materials.

2. Development and testing of methods for determination of vintage and designation of origin of Bulgarian fine vines

Radiological and chemical fingerprinting can help to determine the year of production - vintage and the geographical provenance or designation of origin of high quality wines. Radiological and chemical investigations are performed on Bulgarian Melnik fine wine, as well as, on vineyard soil, grape stems and grape leaves. The gamma-ray activity of the radioisotope Caesium-137 has been measured in wines from different vintages using Low-Background High-Resolution Gamma-Spectrometry. The specific concentrations of 16 metals have been measured in samples from soil, grape stems, grape leaves and fine wine from Shiroka Melnishka variety grown in typical Melnik vineyard by means of Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES). Radiological and chemical correlations obtained were used as initial data base for determination of vintage back to 1986 and for proof of designation of origin of Melnik fine wine. The results of these investigations have been presented on 29th International Horticultural Congress, Symposium 10 "Tropical & Subtropical Wine & Grapes", Brisbane, Australia - 17-22 August 2014

- **Participation in European Network**

FP7-INFRASTRUCTURES-2007-1 NuPNET - ERANET for Nuclear Physics Infrastructures (European contract № 202914. priority COORDINATION AND SUPPORT ACTION (COORDINATION)). Project SARFEN. Project ENSAR.

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LABORATORY: <u>NUCLEAR REACTIONS</u>

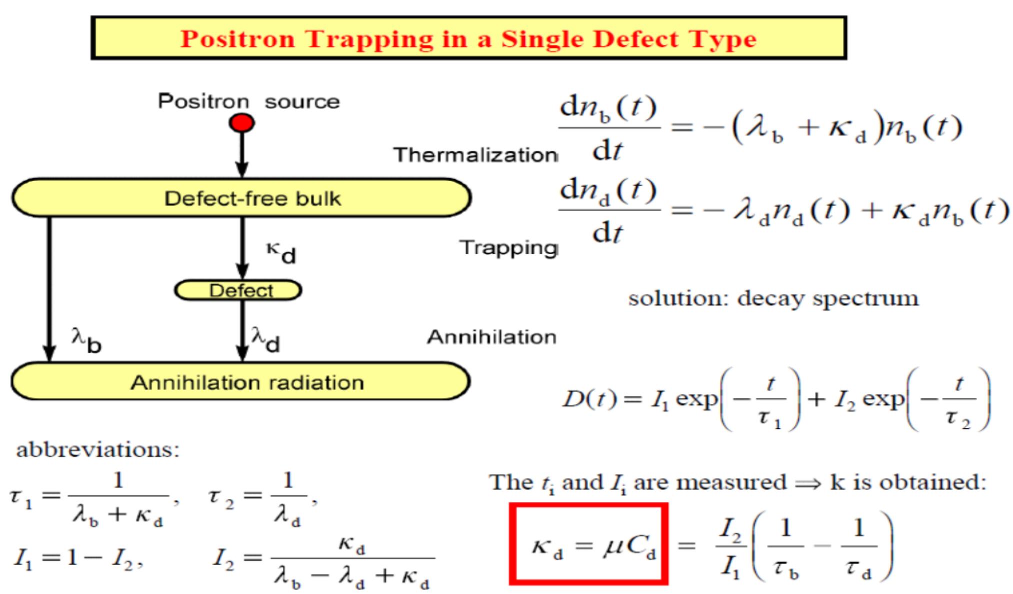
HEAD OF LABORATORY: PROF. DSC PAVEL PETKOV

In 2014, the Laboratory continued the investigations in the fields of Nuclear structure and Nuclear reactions. Combining the plunger method with a study of the hyperfine interactions in nuclei recoiling in vacuum in inverse kinematics the g-factor of the first excited 2^+ level in ^{138}Ce has been determined relative to the g-factor of the analog level in ^{142}Ce. The lifetimes of these two levels were also determined with better precision than that of previous data. Together, these data indicate a closure of the sub-shell $\pi g_{7/2}$ at Z=58. On the basis of full gamma-spectroscopy investigations of ^{102}Rh, observables characterizing two bands candidates for chiral partners have been determined while one of the bands has been observed for the first time. It has been established that the two bands are built on different excitations of the core and their properties do not point at static chirality. In ^{105}Ru, obtained as fragment in fission induced by heavy ions, the coexisting positive parity band-structures found experimentally are well described by calculations within the triaxial rotor plus quasiparticle model. The nucleus ^{96}Ru has been investigated by means of inelasitc scattering of protons including DSAM. This reaction and the lifetime determination method employed will be applied for experiments at the Cyclotron of the INRNE (NCC) which is under construction. Valuable information on the systematics of mixed symmetry states based on octupole and hexadecapole excitations in the isotones with N=52. Two new procedures for analyzing DSAM data and lifetime determination have been developed by us. Their basic idea is the direct use of the line shapes of the transitions depopulating the level of interest and the directly feeding transitions. In this approach the necessity of fitting the time dependence of the levels involved is avoided or strongly reduced. This leads to a substantial decrease of the systematic errors. The nucleus ^{168}Yb has been studied in two different plunger experiments and lifeitmes of levels in the yrast band have been determined using two different procedures developed by us. The behavior of the B(E2)'s indicates a reduction of the collectivity well below the first crossing with the S-band. This particularity is not observed in the neighboring even-even Yb isotopes and has to be explained by dedicated theoretical studies in future. The nucleus ^{180}Os, positioned at the limits of the X(5) island of nuclei in the mass region A~180 was investigated in a plunger experiment. The reduced B(E2) transition strengths, together with other available spectroscopic information, were compared to calculations within the X(5), IBM и GCM models which confirm the transitional character of this nucleus. The work dedicated to investigation of highly-deformed bands in ^{124}Xe, populated by means of a fusion-evaporation reaction in an experiment at GAMMASPHERE, was completed. The results will be published in 2015. An investigation of the nuclei ^{111}Ag и ^{113}Ag obtained as fragments in fission induced by heavy ions is in progress. The studies dedicated to accelerator physics in 2015 involved theoretical investigations and computer modeling of the accelerated charged particle beams as well as development of systems, algorithms and computer codes for diagnostics and automatic control of accelerators. Preparative works dedicated to the future operation of the Cyclotron of the INRNE (NCC) were also undertaken. The experiments on which the activity of the Laboratory is based were performed in collaboration with leading nuclear physics institutions abroad like Legnaro, Cologne, Orsay, Yale and others.

LABORATORY: POSITRON SPECTROSCOPY

HEAD OF LABORATORY: PROF. DSC TROYO TROEV

Positron lifetime spectroscopy is a powerful and sensitive method for studying of defect concentrations as low as 10^{-6} in the lattice of metals. The method is based on the positron trapping at open volume defects. The positron trapping in pure lattice may be used for characterization of mono-vacancies, di-vacancies and vacancy-clusters (nano-voids). The annihilation characteristics of a positron trapped at a vacancy or empty nano-voids are different from those of positrons trapped at nano-voids containing hydrogen or helium.



During 2014 the Positron spectroscopy laboratory continue the participation at the EUROFUSION/INRNE projects concern the model calculations of positron lifetime of defects in bcc structures containing hydrogen and helium, simulations of cascades atom displacements and defects in fusion materials for the first wall and divertor of ITER and DEMO.

In October 2014 in Brussels has been signed the CONSORTIUM AGREEMENT - EUROFUSION for the period of 2014-2020.

Figure 1.

EUROFUSION Grant Agreement signature in Brussels 2014.

The interaction of positrons with defects containing hydrogen or helium illustrates interesting physical concepts concerning hydrogen and helium trapping by vacancy clusters. It is clear that micro-structural information is essential for understanding the helium mechanism in advanced fusion materials. Positron spectroscopy has priority to other methods for investigation of defects in fusion materials.

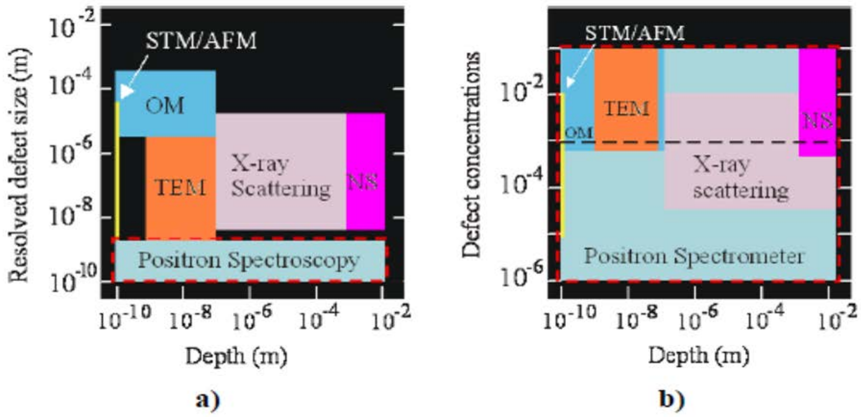


Figure 2. Comparison of positron annihilation spectroscopy to other methods.

Positron spectroscopy laboratory have experimental facilities for measurements of Coincidence Doppler Broadening of Annihilation Gamma-line **CDBAL**, Positron lifetime **PLT** and angular correlation as well as experimental facility for mono-energetic slow positrons. Realistic modeling of material response in a reactor environment requires knowledge of the fundamental physical properties of hydrogen and helium in metals. Hydrogen or helium presences influence the behavior of defects in samples. Helium in metals is studied in connection with tritium, which decay into He^3 in nuclear fusion. Helium-3 produced by the decay of tritium is very efficiently trapped in metals. It is clear that micro-structural information is essential for understanding the helium mechanism in advanced fusion materials. The positron studies are focused on the investigation of defects like vacancies, dislocations, vacancy-clusters, empty nano-voids and nano-voids containing hydrogen or helium in fission and fusion reactor materials. The positrons injected into a solid may get trapped at defects that represent regions in the crystal lattice where the atomic density is lower than the average density in the bulk, i.e. vacancies, vacancy clusters (including voids, bubbles) and dislocations.

Positron spectroscopy laboratory on the basis of the knowledge and expertise in the field of positron physics actively will participate in the future Positron Emission Tomography studies using the INRNE Cyclotron in preparation of positron sources as well as in the studies of the electron properties of materials.

The positron lifetime spectroscopy provides unique information on the local density distribution of point defects, which are key factor for determination of properties and characteristics of structural fusion materials. The methods of modeling the atomic interactions can roughly be divided into three categories: The first principles, or ab initio, methods are the most rigorous ones. Only a few well controlled approximations to exact quantum mechanics are made. Semi empirical methods contain more drastic approximations and may also contain empirically defined parameters. Empirical methods are a group of methods that are tuned to reproduce an empirically defined fitting set. Two Component Density Functional Theory [TCDFT] combined with the Local density approximation [LDA] or generalized gradient approximation [GGA] for the exchange and correlation functional is a powerful method for studying materials properties at the atomic scale. Today, one of the most used methods for performing DFT calculations is the pseudo potential method using periodic super cells and plane-wave expansions for the pseudo-wave functions. In the last years the study of the evolution of defects as well as the ^{4}He and ^{3}H formation in lattice increases, due to the requirements of fusion reactor technology. The created He atoms produce damages not only on the surface but also in the bulk because He easily diffuses into the crystal lattice. In a perfect crystal the positron density is delocalized in the whole lattice while in presence of vacancies the positrons are trapped in open volumes. Due to the lower electron density in vacancies, an increased positron lifetime is measured. Investigations concern to the mechanical properties of materials in the presence of helium clusters are far from complete, although much attention has been paid to intergranular embrittlement. ITER will operate with full metallic walls and this imposes restrictions on the plasma operational space in order to ensure safe operation. The purpose of the modeling studies was determination of the positron lifetimes and positron ground state energies in iron, iron-chromium nano-voids. Atoms, which have less than two lattice constants outside the initial simulation cell, were included in the calculations. In order to investigate the defects distribution in depth, the whole cylinders was divided of thin cylinders with 1 mm thickness, where the dpa was calculated.

The interactions of radiation defects with point and linear defects in metal lattice are of practical importance for the predicative models of mechanical behavior. The excellent agreement between MCNP5 and FLUKA was obtained for Fe is strong evidence that the track algorithms of the both simulation codes work correctly. Additionally, it is successful test for the correct setup geometry built in the two codes. Currently, He-induced effects such as nano-structures or bubbles and their impact on the damage threshold are of particular interest and needs to be investigated as soon as possible. Irradiating the fusion materials with high energy 14 MeV neutrons, results in a wide range of defects. Frenkel pairs are the simple defects created by fast neutrons. The number of Frenkel-pairs created by primary knock-on atoms PKA due to the displacement cascades can be calculated by NRT formula. For fusion neutrons applications, the Monte Carlo code MCNP has become the main computational tool because of its ease and flexibility in modeling of complicated fusion reactor components and its capability for proper simulation of the behavior of the 14 MeV neutrons and of secondary photons as well. FLUKA is a fully integrated particle physics Monte Carlo simulation package. It has many applications in high energy experimental physics and engineering. GEANT4 is a code developed in CERN. Atomistic computer simulations have played an important role in the development of our understanding of materials. During 2014 one student prepare his Diploma work ‘Simulation of positron interaction in materials for thermonuclear reactors” in positron spectroscopy laboratory and successfully defense his work in Physics Faculty of Sofia University.

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We carry out positron studies with physicists from Reactor Research Institute, Kyoto, Japan, Aristotle University, Thessaloniki, Greece, Nuclear Department of the University of Bratislava, Slovakia, University of Bristol, UK, Max-Planck Institute, Stuttgart, Germany.

NEUTRON AND REACTOR PHYSICS

LABORATORY: NEUTRON DATA AND NUCLEAR-PHYSICS RESEARCH

HEAD OF LABORATORY: ASSOC. PROF. DR NINA KOYUMDJIEVA

The scope of science research in the Laboratory is reflected in two project tasks in the framework of the INRNE scientific program. These include nuclear physics investigations on neutron sources in JINR, Dubna and receiving the evaluated neutron data files on the base of the experimental data, obtained at GELINA in IRMM, Geel.

The multi-detector systems type «Romashka» developed at the Frank Laboratory of Neutron Physics of the JINR-Dubna can be used in different types of experiments in which the gamma-quanta from the reactions of neutron capture or inelastic scattering of neutrons are registered. These detectors are an important research tool for obtaining new nuclear data.

The results of the scientific research conducted at the JINR-Dubna in 2014:

- A method for studying the response function of the 24 modular «Romashka» in two geometries: compact and test was developed.

It allows the gamma-ray energy released in each section of the detector, total energy release, multiplicity spectrum, registration efficiency and other data to be obtained.

This preliminary work will help in preparation for the experiment in which the efficiency of gamma quanta registration can only be obtained on the basis of model calculations.

- In the frame of TANGRA-project the JINR Romashka (24 sections) was tested upon the registration of gamma-quanta from the reaction of inelastic scattering of 14 MeV neutrons from a graphite sample - reaction 12C (n, n'g)12C.
- The degree of the attenuation of the 14 MeV neutrons from a 50 cm-thick combined shielding-collimator, protecting the neutron- and gamma detectors of «Romashka», was investigated in order to find the most suitable for the planned experiment configurations of the shielding-collimator (Fe and Pb).
- The characteristics of the pre-selected shielding-collimator configuration of detectors 24-section "Romashka" were studied in details.

Measurements have been performed at the GELINA facility to determine the average cross section for the ^{197}Au (n, γ) reaction in the 3.5 keV - 84 keV energy region. Using an internal normalization procedure, the systematic uncertainty related to the normalization and weighting function has been reduced to below 1%. An additional uncertainty of 0.5% has resulted from the correction for self-shielding and multiple interaction events. A full covariance matrix has been produced by propagating both uncorrelated and correlated uncertainties. Average resonance parameters, *i.e.* an orbital independent scattering radius R', neutron strength functions $S_{l=0,1}$ and capture transmission coefficients for *s*-waves $T_{\gamma,0}^{2^+}$ and *p*-waves $T_{\gamma,0}^{2^-}$, together with their covariance matrix have been derived in a simultaneous least squares fit to the measured average capture cross section and the experimental average total cross sections reported in the literature. In addition, Maxwellian average cross sections at different temperatures have been calculated. The data obtained have confirmed the 6% bias in the cross sections used for astrophysical applications.

The newly obtained ENDF-compatible evaluation for the neutron-induced reaction cross-sections of ^{197}Au has been implemented in the latest release of the European Nuclear Data Library JEFF-3.2 maintained by the OECD Nuclear Energy Agency. The improved evaluation methodology in the gold unresolved resonance region has included analysis of dispersive coupled-channel optical model data, correction of the ENDF approximation for orbital momentum conservation, and covariance information on the resulting optimized parameters. The resolved resonance region up to 2 keV has been represented in the Reich-Moore formalism preserving the values of both the thermal capture cross section and the coherent scattering length. The parameters of the resolved resonances have been determined in optimization on transmission and capture data measured at the time-of-flight facilities GELINA and n_TOF.

An effort has been devoted to the update of ^{238}U reaction cross sections in the energy region of unresolved resonances. New versions of ^{238}U have been evaluated for the JEFF project targeted to further consideration in both the Collaborative International Evaluated Library Organization (CIELO) Pilot Project of the OECD/NEA and the Neutron Cross-Section Standards Project of the IAEA. After processing with the NJOY code to test the application consistency and to produce a continuous-energy data library for Monte Carlo codes, the preliminary uranium evaluations have been distributed to the JEFF community for an extensive validation test.

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LABORATORY: <u>REACTOR PHYSICS</u>

HEAD OF LABORATORY: ASSOC. PROF. DR MARIA MANOLOVA

The work of the Laboratory was focused on the analysis of core behaviour, reactor vessel lifetime and spent fuel of VVER using deterministic and Monte Carlo codes. Part of the studies was performed in the frame of the NURESAFE EU project. Other topics of research were innovative methodologies for nuclear reactor simulation, such as higher-resolution models and high-performance computing (HPC) on multi-core systems supplemented with graphical processor units (GPU).

<u>Modelling of the reactor core behavior</u>

Simulation methods in reactor physics

Improved calculation schemes for cross-section library generation with the higher-order linear-surface method of characteristics (LS MOC) and other recent developments in APOLLO2 were implemented to nodal and pin-by-pin cross-section library generation.

Optimized distributed computation techniques using portable batch system (PBS) techniques were implemented for the generation of cross-section libraries on multicore workstations. This work was carried out in the frame of the CEA-INRNE Specific Topic Collaboration on “Simulation in Reactor Physics and Multi-physics”.

Parallelized CudaC/C++ variants of the Bi-Conjugate Gradient Stabilized (BiCGStab) method using multicore CPU and GPU were investigated. The specific objective is their implementation for HPC in the COBAYA core physics code. This work was performed in collaboration with Universidad Politecnica de Madrid (UPM) and in the frame of the EU NURESAFE project.

Development work for 3D transport reference solutions for VVER lattices through coupled Monte Carlo/TH solutions with MCNP6/COBRA-TF was carried out in collaboration with the Pennsylvania State University.

Transient reactor analysis

An improved multi-1D CATHARE2 VVER-1000 system model with 24-sector azimuth mesh in the reactor vessel was tested against plant data, to be used for standalone and coupled TRIO-U/plant system simulations. An updated full-core COBAYA3/COBRA coupling at the nodal level was tested for main steam line break

(MSLB) analysis, to provide independent solutions for verification of the core N/TH couplings of EU NURESAFE codes in the Salome platform.

Simulation platform for nuclear reactor safety (NURESAFE) – an EU project

The EU NURESAFE project (2013-2015) is partially funded by the EC under the FP7/Euratom contract no. 323263 and is co-funded by the Bulgarian Ministry of Education and Science, contract no. D01-191/15.07.2014. INRNE leads work package WP1.4 devoted to multi-physics VVER reactor simulation and participates in WP1.1 on parallelized reactor physics calculations.

The situation target for multi-physics calculations is a VVER MSLB accident. In 2014, multi-parameter cross-section libraries at the nodal and fuel pin level were generated and tested, using wide parameter range and optimized parameter grid, as well as improved calculation schemes with APOLLO2.

Full-core COBAYA3/FLICA4 and COBAYA3/COBRA coupled neutronic/thermal-hydraulic models at the nodal level were tested in VVER-1000 MSLB simulations.

Sub-channel COBRA-TF thermal-hydraulic models were tested for core subsets against plant data and code-to-code, in steady state and transient analysis. The COBRA-TF Application Program Interface (API) for Salome 6.6 was adapted to hexagonal geometry.

Standalone COBAYA models of pin-by-pin neutronics in hexagonal geometry were tested against transport reference solutions and N/TH coupling at the pin-cell level for core sub-sets up to mini-cores.

A CATHARE2/TRIO_U coupled simulation was validated against Kozloduy-6 plant data, in a joint task of UJV Rez-INRNE.

<u>Spent fuel analysis</u>

Nuclear safety of spent nuclear fuel management is ensured by implementation of the basic safety functions: providing subcriticality, residual heat removal and retention of radioactive products within the physical barriers. To ensure subcriticality during both normal operation and design basis accidents the effective multiplication factor of neutrons K_{eff} must be lower than 0.95. An evaluation of criticality of spent fuel facilities have been made by the modular code system SCALE. The basic calculations are performed with version 6.1 and are validated with version 6.0 of the code system. Spent fuel assemblies type TVSA are modelled as they are representative for VVER-1000 nuclear fuel and cover the characteristics of the earlier modifications of the fuel assemblies. The modelling of the spent fuel containers and equipment is in accordance with actual geometric dimensions and material composition. In all performed calculations, the results demonstrate that the criticality safety criteria are achieved and the effective multiplication factor K_{eff} is lower than the regulatory requirements.

New investigations on the spent fuel storage were performed in 2014. Verifications are carried out to demonstrate that the fuel can be stored safely and can be transported after storage. An accurate prediction of the spent fuel characteristics is mandatory for safety and economic reasons. The methodology of prediction of the thermo-mechanical properties of spent nuclear fuel rod under long dry storage includes calculations with different codes that cover different periods of the fuel life (irradiation, cooling and dry storage.

Knowing the isotopic composition of the fuel at the time of discharge is a prerequisite for residual decay heat and fast neutron flux calculations. The last version of the modular code system SCALE 6 was applied to evaluate the isotopic concentrations at the nodal level using spectrum history and power density. The linear heat rate in the out of reactor conditions was assessed from the residual decay heat in the fuel rod.

The simulation started with TRANSURANUS code prediction of fuel rod status after 4 years operation in the Russian type reactor VVER-440. During the next steps of the fuel rod life, cooling in the pool and dry storage in He atmosphere, the linear heat rate, the fast neutron flux and the cooling conditions are considerably different. The coupling with SCALE6 code system will provide basis for fuel performance simulation during wet and long term dry storage in Spent Fuel Storage Facility.

<u>Neutron/gamma transport modeling</u>

Neutron fluence validation of the VVER-1000 reactor pressure vessel of Kozloduy NPP Unit 5 was carried out under contract with Kozloduy NPP Plc.

The validation of neutron fluence has been carried out by ex-vessel measurements with activation detectors placed in the air cavity behind the reactor vessel of Kozloduy NPP Units 5 after 20^{th} cycle. Following activities have been carried out:

- Dismounting of the Fe-, Cu- and Nb-detectors irradiated in the air cavity behind the pressure vessel during Cycles 19 -20 of Unit 5;
- Installation of an ex-vessel device with activation detectors at Unit 5 for irradiation during the next cycles
- Calculation of the RPV neutron fluence and induced activities for Cycles 19 -20 of Unit 5 by numerical modeling using the 3D code TORT

Improved calculations schemes for determination of the neutron fluence, activity and dose

The implementation of the MCNP Monte Carlo code for more precise determination of neutron/gamma fields is the next step in improving the INRNE transport calculations methodology. 3D source routine was developed for VVER-1000 fixed source definition. Initial calculations were performed for determination of the neutron fluence, activity and dose based on the Monte Carlo method. Experimental confirmation of the results was obtained. Scientific report was prepared and submitted to the National Scientific Fund.

Modeling of Boron Neutron Capture Therapy channel for the IRT- Sofia research reactor

The 3D investigation of IRT-Sofia BNCT channel's is being continued using an improved Monte Carlo calculation scheme. The characterization of Al_2O_3 and Carbon as a filter/moderator materials was completed. The biological effects of the epithermal neutron beam formed by the three filter/moderator materials was evaluated in phantom. The results of the calculations show, that in any of the cases IRT-Sofia will be able to deliver a high quality epithermal beam for BNCT.

Neutron Transport Modeling Uncertainty Reduction in Homogenous and Heterogeneous Media

Joint study in the frames of the project “Optimization of uncertainty reduction in the mathematical modeling of neutron transport in homogeneous and inhomogeneous media” by INRNE BAS and Institute for Nuclear Research of Russian Academy of Science is carried out under cooperation between Bulgarian Academy of Science and Russian Academy of Science. The period of the agreement for the study between the Academies is 2012 – 2014. In 2014 the study was focused on investigation of the results from the calculations carried out by the MCNPX code so far. The same code is planned to be used for solution of another task of the joint study – modeling of capture neutron detectors with the purpose to improve their resolution abilities and efficiency. Further collaboration in this field is planed that is especially important taking into account the INRNE intention to operate cyclotron accelerator in the near future.

Nuclear fuel modelling by the TRANSURANUS fuel performance code

During 2014 started the work in the frame of the IAEA research contract No:18411/R0 entitled "Fuel Performance Modelling under LOCA and RIA Conditions" which forms a part of the IAEA's Coordinated Research Project "Fuel Modelling in Accident Conditions(FUMAC)"

The team made some predictions for experiments that provide support for verification and validation of the TRANSURANUS (WWER) code for design basic accident (DBA) simulations. In particular the attention was given to simulate the first stage of a severe accident, when cylindrical fuel rod geometry is still preserved. Analysis concern the fuel central temperature during the ramp irradiation, the pin pressure during accident progression and the fission gas release and gas mixture have been performed.

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NUCLEAR ENERGY

LABORATORY: <u>NUCLEAR ENERGY AND NUCLEAR SAFETY</u>

HEAD OF LABORATORY: ASSOC. PROF. DR PAVLIN GROUDEV

Collaborators: Assist. Prof. Antoaneta Stefanova, Assist. Prof. Marina Kadreva, Assist. Rositca Gencheva, M.Sc. Boryana Atanasova, M.Sc. Petya Vryashkova, Assist. Neli Zaharieva and Assist. Petya Petrova

More than 15 years Nuclear Energy and Nuclear Safety Laboratory (NENS) works in the field of safety of Nuclear Power Plants. The main activity of the research team is analysis of the development of the emergency assessment of the safety systems and the analysis of the actions of the operating personnel.

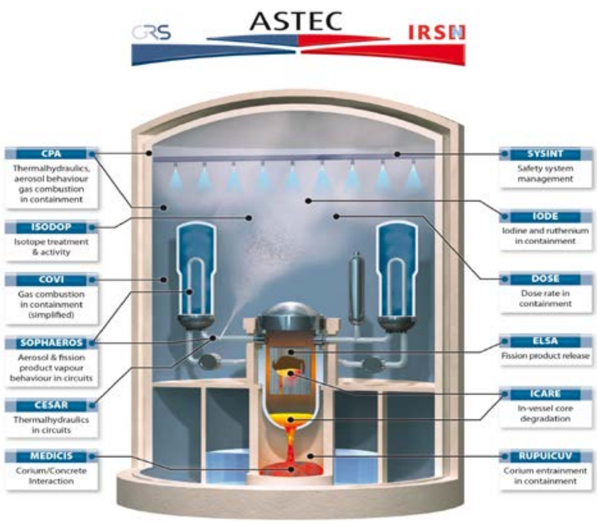
Since its establishment until now the NENS laboratory has established itself in the field of plant safety by participating in many national and international projects. The specialists have experience in application of thermohydraulic codes like RELAP and CATHARE and severe accident codes (MELCOR, ASTEC and RELAP/SCDAP). During 2014 the laboratory NENS continued participation of in 7th framework programme of the European Atomic Energy Community (EURATOM) for Research and Training Programme on Nuclear Energy.

Some of the projects are listed below:

- ✓ **Code for European Severe Accidents Management (CESAM)**

Within the CESAM project INRNE together with different organizations continues collaboration on the adaptation and qualification of the integral code ASTEC. This code is developed by IRSN and GRS and describes the behavior of whole NPP under severe accident conditions.

Main objective of the project is consolidation of ASTEC integral code as European reference tool for severe accident management (SAM) in all European NPPs of Generation II-III (PWR, BWR, CANDU) for severe accident scenarios with special consideration of the Fukushima accident.



Some of the obtained results in 2014 are published in journals “Nuclear Engineering Design”, “Annals of the Nuclear Energy” of ELSEVIER LTD and “Science and Technology Journal of BgNS and presented on the international conference. The other papers have been approved and prepared for publication.

In the frame of CESAM project a research from the Laboratory was invited to work for Innovative Systems Software (ISS), Idaho, USA for 4 months. The training was focused on the application, validation and improvement of RELAP/SCDAPSIM for VVERs. As a result of this work the code will apply to selected experiments from the German CORA and Quench programs and/or Russia parameter experiments.

- ✓ **Advanced Safety Assessment: Extended PSA (ASAMPSA_E)**

The objective of the ASAMPSA_E project is to examining in detail how far the PSA methodologies are able to identify any major risk induced by the interaction between a NPP and its environments, and to derive some technical recommendations (guidelines) for PSA developers and users.

Launched after the Fukushima Daiichi accident, the project will pay attention to the risks induced by possible natural extreme external events and their combinations. The main outcomes of the project consist in developing guidance documents with the objective to help European stakeholders to develop efficiently extended PSA and verify that all dominant risks are identified and managed. The project has significant importance for harmonization of PSA methodology in the Euratom framework programme.

In the frames of the current project, the main topics of our work are: a review of the requirements for ensuring the safety of nuclear power plants – the requirements related to the risk informed decision making (defence in depth concept and requirements for safety assessments); the role of Severe Accident Management Guidelines (SAMGs) in ensuring the safety of NPPs; PSA contribution in the development and application of SAMGs.

The perspectives for PSA contribution to SAM development were investigated. The review of areas where PSA could contribute to the development and implementation of SAMGs were studied based on WENRA and IAEA documents.

- ✓ **Activities of the Nuclear Fuel Performance and Analysis (NFPA) Group**

The NFPA Group, in the frame of the NENS Laboratory, has been established in 1993. The Group staff members are: Assist. Prof. Svetla Stefanova, Assist. Prof. Guner Passage, Master of Maths. Ivatz Mandev, Master of Eng. Violeta Hristova, Tech. Assist. Maya Georgieva and Assist. Prof. Mitka Georgieva (part-time).

The NFPA scope of activities include: (1) Calculations and analyses of the WWER fuel rod thermomechanical behaviour at steady-state, transient and accident conditions, applying the PIN-micro / PINw99, FEMAXI-6 and the TRANSURANUS codes, to justify the safe and reliable operation of the nuclear fuel at the Kozloduy NPP; (2) Development, implementation and validation of models and computer codes for thermomechanical calculations and analyses of WWER and LWR fuel rods. (3) Organisation of series of 10 biannual international conferences (since 1994) on “WWER Fuel Performance, Modelling and Experimental Support”; preparation and publication of conference proceedings hard-copy books.

The work performed in 2014 consist of: (1) Support to the Kozloduy NPP in translation of specialised scientific-technical documentation for the implementation of a new improved type of fuel in the units 5 and 6 with WWER-1000 reactors; (2) Editorial and proof-reader’s work during the pre-print preparation and release of the 10th International Conference on WWER Fuel (Sandansky’2013) proceedings book, 600 pages in English, and (3) Preparation of a thematical practicum (not finished) on nuclear fuel behaviour modelling, code application and analysis for students education at Sofia University, Faculty of Physics.

NUCLEAR METHODS

LABORATORY: NUCLEAR ELECTRONICS AND MEUSBAUER SPECTROSCOPY

HEAD OF LABORATORY: ASSOC. PROF. DR LYUBOMIR DIMITROV

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The one of main activities in 2014 was the development of a new multichannel dosimetric system, able to control the accumulated dose of different radiation sources – particles and photons. Such a system could have wide application in CMS sub detector's radiation hardness investigations and in other similar tasks.

The new system is based on the preceding one, designed for gamma radiation only [1]. The main difference (fig. 1) is in the radiation detectors, included in each sensor: in addition to the two gamma ray detectors, based on the field effect transistors, two pin-diodes are added, measuring the dose of the protons and neutrons. This change requires the development of a new version of the main controller, capable to read four detectors in each sensor. A supplement limitation was to realize this new extension on a separated PCB, which can be installed on the base PCB by connectors.

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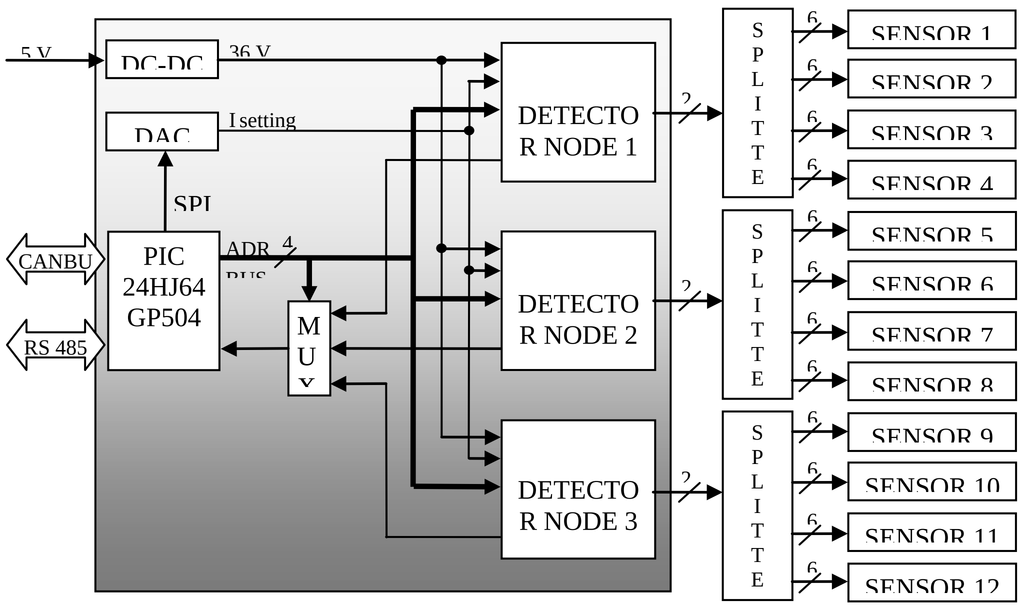


Fig. 1.

7-th Frame Program and co-financed by the Bulgarian National Fund of Scientific Investigations

Another important activity during 2014 was the development of a production

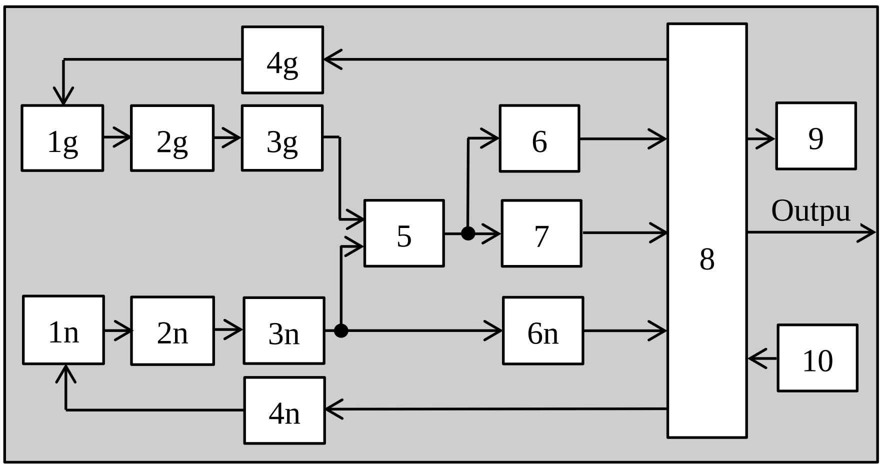


Fig. 2

prototype of a portable radiometer/spectrometer for gamma and neutron radiation (fig. 2). It contains two similar channels: with index “g” for gamma radiation and with index “n” for neutrons. Each block 1 is a radiation gas filled detector (Xe for gamma and ^3He for neutrons), blocks 2 are charge-sensitive preamplifiers, blocks 3 – pulse-shaping amplifiers, blocks 4 – detector’s power supply, blocks 6 – single channel analyzers, ensuring the noise discrimination. Block 5 is a linear OR Gate, and block 7 – a peak detector. Block 8 is a one-chip microcontroller (with an embedded 12-bits ADC), which controls the operation of entire device. It sets the detector’s high voltage and the analyzer’s thresholds. It receives the pulses from both channels, calculates the radiometric results and display them on the screen and sound block 9. Using the peak detector and it’s ADC, the controller generates an amplitude spectrum information, which is provided at the device output PC and can be processed and displayed by an outside computer (using an RS485/USB interface).

Block 10 is a NiMH battery (3,6 V, 0,730 mAh), ensuring the autonomous operation of the device during 20 hours.

1. Dimitrov, L.P., P.S. Iaydjiev, G.M. Mitev, I.V. Vankov. Radiation Monitoring at the New GIF++ Irradiation Facility at CERN. Proc. of XXIV Int. Symp. on Nuclear Electronics & Computing (NEC`2013), Dubna, E10,11-136, 2013, p. 74.

MÖSSBAUER SPECTROSCOPY

In 2014 the main activity was the application of Mössbauer spectroscopy for study of magnetic materials and magnetic nanostructures.

1. **Carbon particles synthesized by pyrolysis in a sealed container.** Different types of carbon structures as perfect in shape spheres, ellipsoids and nanobelts have been produced by pyrolysis in a hermetically sealed stainless steel container. Aromatic hydrocarbons like benzene, toluene, xylene and their mixtures with water have been used as starting materials. The experiments have been made at a temperature in the range of 400–600˚C. The temperature is growing at a rate of 300˚C/min. Than a cooling at rate of 30˚C/min takes place. Particle morphology has been examined by Scanning and Transmission Electron Microscopy (SEM, TEM) and the chemical composition and structure via X-ray diffraction (XRD) and infrared spectroscopy. As a result we obtained spherical and ellipsoid particles from pure incompletely graphitized carbon. They are stable up to 600˚C in air and remain unchanged up to 1000 ˚C in vacuum.

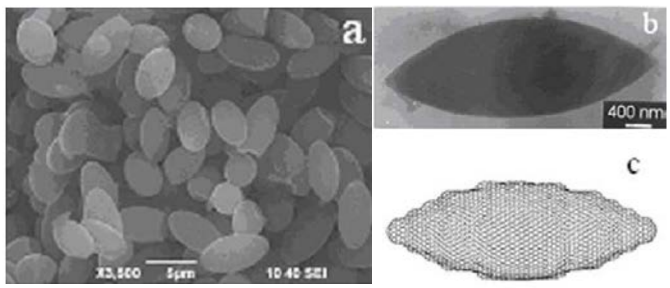
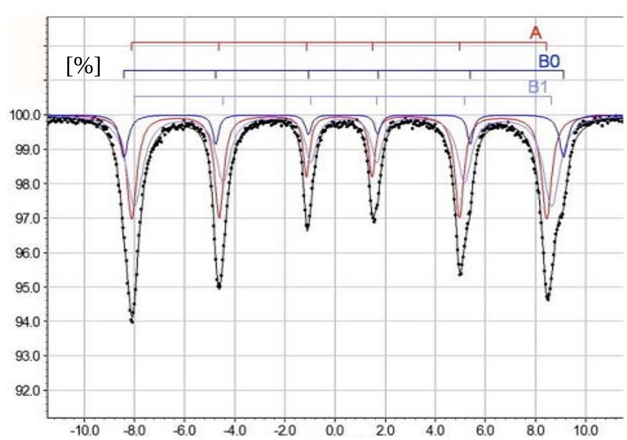


Fig. 1. Ellipsoidal carbon particles: a) – a SEM picture; b) – a TEM picture and c) – an ellipsoidal nanoparticle model.

2. **Nanosized cobalt ferrite particles in silica matrix – synthesis and characterization.** Magnetic nanoparticles of cobalt ferrite were synthesized by solution combustion synthesis technique. The method is based on combustion reaction of metal nitrates (oxidizers) and some organic reducers (glycine, urea, citric acid etc.) acting as a fuel. As starting reagents cobalt and iron nitrates and sucrose were used. The as-prepared materials consist of crystallites with mean size of about 3 nm. Additional thermal treatment at different temperatures for 1 hour was applied to obtain cobalt ferrite nano-particles with mean size in the range of 10-50 nm. Silica-$CoFe_2O_4$ composite was prepared by adding cobalt ferrite powder to silica solution followed by 30 min sonication. The obtained suspension was spilled into Petri-dishes and dried. X-Ray diffraction (XRD), Electron Microscopy (TEM, SEM) as well as Mössbauer spectroscopy were used to characterize the $CoFe_2O_4$ – phase and the composite. Several factors were found to influence the distribution of magnetic particles within the silica matrix.



Velocity [mm/s]

Fig. 2. Mössbauer spectrum of silica-$CoFe_2O_4$ composite (concentrated solution)

3**. A new type of gas flow cryostat in the temperature range of 5 – 300 K at a low cooler consumption.** A new type of a gas flow cryostat is designed and constructed, where the sample temperature can be changed within the range of 5-300 K. The getter containing part of the cryostat is immersed in a standard cryogenic storage dewar with a liquid helium inside. With respect to the conventional gas flow cryostats, in the new one the sample is cooled by the helium vapors without additional heating of the liquid. For this purpose the helium vapor pressure is maintained at a little above the atmospheric pressure. The temperature change/control is reached via change/control of the cooling gas flow, and via a miniature heater placed in close vicinity of the sample. Computerized electronics maintains an automatic change of the temperature and its stabilization at accuracy of 0.1 K. The new cryostat can be applied in a Mössbauer and other studies of various samples, including nanomaterials.

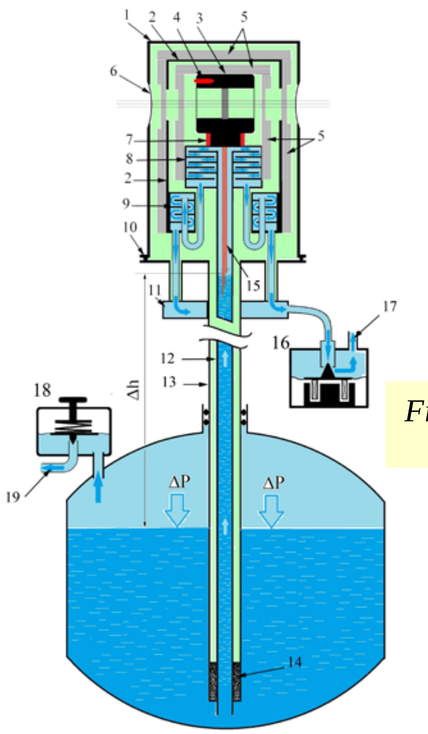


Fig. 3

1. Vacuum jacket
2. Thermal screen
3. Sample holder
4. Temperature sensor
5. Thermal insulation
6. Window
7. Heater coil
8. Heat exchanger
9. Heat exchanger
10. Vacuum seal
11. Exhausted He-vapors
12. Cooler tube
13. Vacuum tube
14. Getter
15. Thin Cu-wires
16. Electromagnetic valve
17. Exhausted He vapors
18. Manual valve
19. He-vapors

1. CARBON PARTICLES SYNTHESIZED BY PYROLYSIS IN A SEALED CONTAINER
N. Koprinarov , M. Konstantinova , Ì. Petrov , T. Ruskov
Nanoscience & Nanotechnology, 14
eds. E. Balabanova, E. Mileva, Sofia, 2014 43-45
2. NANOSIZED COBALT FERRITE PARTICLES IN SILICA MATRIX –
SYNTHESIS AND CHARACTERIZATION
Ts. Lazarova , S. Atanassova-Vladimirova , T. Ruskov , D. Kovacheva
Nanoscience & Nanotechnology, 14
eds. E. Balabanova, E. Mileva, Sofia, 2014 129-132
3. A NEW TYPE OF GAS FLOW CRYOSTAT IN THE TEMPERATURE RANGE OF 5 – 300 K
FOR MÖSSBAUER SPECTROSCOPY MEASUREMENTS OF NANOMATERIALS
I. Spirov, T. Ruskov, L. Dimitrov
Nanoscience & Nanotechnology, 14
eds. E. Balabanova, E. Mileva, Sofia, 2014 187-189

LABORATORY: NEUTRON AND X-RAY RESEARCH

HEAD OF LABORATORY: PROF. DSC KIRIL KREZHOV

In 2014, the research was focused on the topic "Neutron scattering methods in condensed matter" as a part of the project "Applications of nuclear methods in studying materials". Experimental and theoretical studies of the fundamental laws of the static and dynamic structure of the condensed matter, involving use of different neutron methods and computer modelling techniques, is carried out. In this respect proposed and after successful ratings were executed short-term experiments in the Budapest Neutron Centre of Hungarian Academy of Sciences, the Laboratoire Leon Brillouin (LLB) of CEA-Saclay and the FRM-II research reactor (Technical University of Munich) facilitated by the Neutron-Muon Initiative (NMI3) of EU-EP7 and long term experiments using the time-of-flight instruments DN2 and DN12 at the pulsed reactor IBR-2M of JINR.

A) Substances with strong magnetoelectric effects

By definition, the magnetic multiferroics may maintain induced magnetization with the application of the electric field and electric polarization by means of a magnetic field, and thus, they have a huge variety of potential applications not only in the field of spintronics, in which the information is encoded by the spin polarization of the electrical current, but also in the magnonics that use magnetic excitations and spin waves for information processing.

1. Crystal structure and magnetic ordering in nanosized Y-type hexagonal ferrites

$Ba_2X_2Fe_{12}O_{22}$ (X is Zn^{2+}, Mg^{2+} etc.) are reported as Y- type hexaferrites - important high frequency soft magnetic substances owing to their strong planar anisotropy and high magnetic susceptibility. We investigated the structural and magnetic properties of $Ba_2Mg_2Fe_{12}O_{22}$ powder materials with mean crystallite size below 100 nm synthesized by sol-gel auto-combustion and by co-precipitation. The two techniques produced substances of different homogeneity with respect to the particles' size, and to a different degree of sintering following an identical annealing process. The co-growth observed of the hexagonal particles in the substance obtained by co-precipitation makes this technique suitable for sintering of bulk materials. The Rietveld refinement of XRD and

NPD patterns confirmed the rhombohedral symmetry of the crystal structure with unit cell parameters a = b = 5.8694(1) Å and c = 43.4962(1) Å (hexagonal setting). For $Ba_2Mg_2Fe_{12}O_{22}$ annealed at 1170°C it was established that, in contrast to $Ba_2Zn_2Fe_{12}O_{22}$ structure where the Zn^{2+} cations occupy only tetrahedral cation positions, the Mg^{2+} cations are distributed over all cation positions leading to mixed occupancies of positions in the cation sublattice. Unlike single crystalline $Ba_2Mg_2Fe_{12}O_{22}$, which has a relatively high magnetic transition temperature (~ 200 K) the phase transition from the ferromagnetic to the spiral spin ordering occurred at 183 K and the subsequent transition to a longitudinal conical magnetic structure took place below 40 K.

2. Structure and magnetic properties of fibrous Fe–Al–O mats prepared by electrospinning

The properties of new Fe-Al-O fibrous materials obtained by applying the innovative method of electrospinning using either ferric nitrate or ferric citrate based precursor, was investigated with magnetometry (PPMS) and X-ray diffraction(XRD). It was confirmed that the electrospinning technique with successive steps of calcination of the product provides a reproducible route for fabricating of Fe-Al-O non-woven mats. The XRD patterns revealed the phase $FeAlO_3$, along with traces of unreacted impurities. The $FeAlO_3$ structure is described in orthorhombic space group symmetry $Pna2_1$. The compound exhibits piezoelectricity, ferrimagnetism and magnetoelectric effects at low temperatures. The Fe-Al-O substance fabricated from the citrate based precursor was composed of long filaments of uniform size ranging in diameter between 30 and 50 nm that are more than an order of magnitude thinner than those from nitrate based precursor. The ferric citrate based material is with much less topological defects, improved morphology and a higher content of the orthorhombic $FeAlO_3$ phase. Nevertheless, unlike the known bulk material obtained by classical routes, the fiber material exhibits a lower value of saturation magnetization and the magnetic transition occurs at a much lower temperature.

B) Short range order in amorphous systems from neutron diffraction and RMC modelling

Rare-earth molybdate phases exhibit a great variety of important physical properties including high ion and electron conductivity of fast oxide ion conductors, non-linear optical response and luminescent properties. Neutron diffraction study using instruments PSD (λ_0=1.068 Å) at the BNC and 7C2 at the LLB-CEA-Saclay (λ_0=0.726 Å) has been performed on binary $90MoO_3$-10 Nd_2O_3 and ternary $50MoO_3$-25 Nd_2O_3-$25B_2O_3$, $40MoO_3$-30 Nd_2O_3-30 B_2O_3, 20MoO3-30 Nd_2O_3-50 B_2O_3 (mol%) amorphous systems prepared by melt quench technique. B_2O_3 was isotopically enriched in ^{11}B (99.6%) in order to reduce the influence of the high neutron absorption of ^{10}B present in natural boron. The network structure was modeled by reverse Monte Carlo simulation method. The RMC minimizes the squared difference between the experimental S(Q) and the calculated one from a 3-dimensional atomic configuration. Figure 1 shows the experimental *S(Q)* data for the investigated samples together with the results of RMC simulation.

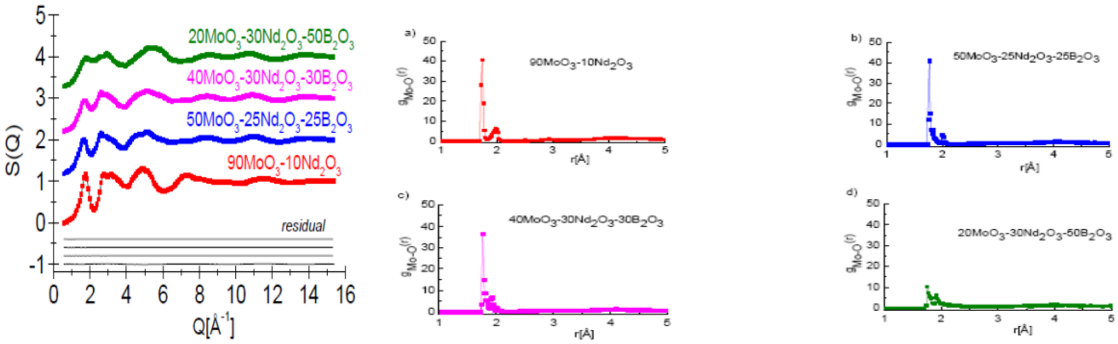


Figure 1. Structure factor of the boromolybdate glasses: experimental data (marks) and RMC simulation (solid line). The residuals of the experimental $S_{EXP}(Q)$ and calculated $S_{RMC}(Q)$ are shown at the bottom of the figure. (The curves are shifted vertically for clarity). The partial atomic correlation functions a), b), c) and d) as well as the coordination numbers have been revealed from the RMC modeling

In summary, we find that: 1- In the binary glass MoO_4 (55%) and MoO_6 (45%) structural units are present; 2- In the ternary system mainly MoO_4 units are present, and with decreasing MoO_3 concentration, the ratio of MoO_6 units roughly decreases; 3- In the ternary glasses the B-O network is formed by BO_3 and BO_4 groups, and with increasing B_2O_3 content conversion of BO_4 to BO_3 takes place; 4- In the ternary system pronounced intermediate range order exists, which indicates mixed MoO_4-BO_4 and MoO_4-BO_3 linkages.

C) Application of the instrumental NAA technique to biogenic iron oxides

The k0-standardization neutron activation analysis (k0-NAA) method was used to analyse the elemental constitution in the products of the bacteria of group Sphaerotilus – Leptothrix, which can be found in different natural habitats. As a result of their metabolism, this group of “iron bacteria” form biogenic iron oxides/(oxy)hydroxides, accumulated in their sheaths (Figure 1, right panel). In general, iron bacteria obtained at different environmental conditions find important application as pigments, catalysts, absorbents etc. We compared the elements accumulated in the bacterial biomass across the set of samples grown on artificial nutrition media under different laboratory conditions with those collected from a high Mountain natural habitat (Figure 1, left panel). The samples were irradiated in the reactors BRR in Budapest and FRM-II in Munich and the contents of As, Cd, Br, Cl, S, Na, Ca, Cs, Cu, Cr, Co, Fe, Mn, Sc, Zn, Pb, Sb, Sm, Th, U and their radionuclides were determined. The data clearly indicate a strong increase in the iron content, which depends on the culture medium and is superior in the so-called Isolation medium. The enrichment rate varied between 3.8 and 7.4 as compared with the reference samples (product of nature). Additional interest comes from the registered highly selective increase of several essential elements which supports the ability of the NAA technique to reveal and quantify the presence of specific trace elements in the biosphere. Further NAA investigations are in progress with the aim to help in revealing an optimized scheme for isolation and enrichment of bacteria in laboratory conditions and possible implications for nanotechnology.

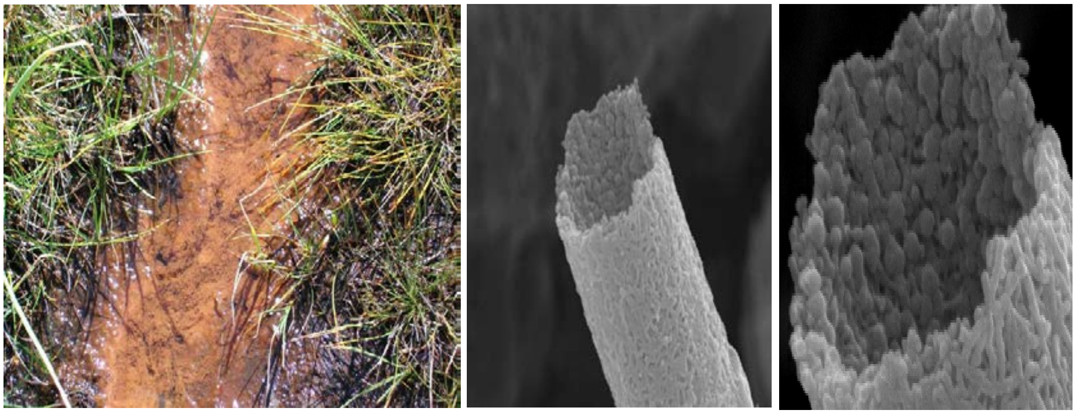


Figure 2. Typical bacterial deposits in the water flow in Vitosha Mountain (Left) and Scanning electron images of the microtubules produced by Leptothrix ochracea

Projects:

1) „Novel magnetic and magnetoelectric materials for next generation electronic components" – contract DO-024 with the National Science Fund at the Ministry of science and education, main contractor INRNE-Sofia; NSF conclusion for successful completion in August 2014. Project leader on behalf of the INRNE group Prof. DSc. K.A. Krezhov

2) „Neutron scattering studies of the short and long range crystalline and magnetic order in solid state materials", collaboration ISSPO (HuAS) – INRNE (BAS), contract BAS- HuAS 2013-2015, Project leader on behalf of the INRNE group Prof. DSc. K.A. Krezhov

3) „Structural investigations of crystalline and amorphous materials by neutron scattering", in the list of Priority topics for collaboration JINR (Dubna) – INRNE (Sofia), Project leader on behalf- of the INRNE group Prof. DSc. K.A. Krezhov

In 2014, members of the Laboratory contributed to 5 peer-reviewed articles in international journals and in proceedings of international conferences.

RADIO-ECOLOGY AND ENVIRONMENT

LABORATORY: RADIOANALYTICAL METHODS

HEAD OF LABORATORY: ASSIST. PROF. BOZHIDAR SLAVCHEV

The Laboratory of Radioanalytical Methods was found more than 40 years ago. The main fields of interest are radiological analysis of alpha, beta and gamma emitters in environmental samples, radioactive waste, and technological products; development of radioanalytical methods for determination of different radionuclides and preparation of standard radioactive sources.

The Laboratory of Radioanalytical Methods is a part of the Quality Management System at INRNE, according to Standard ISO 9001:2008 and Environmental Management System, according to Standard ISO 14001:2004.

The main research activities during 2014 were focused on the following topics:

1. Development of methods for determination of alpha and pure beta emitters in environmental samples, radioactive waste, water, aerosol filters and technological products

Laboratory “Radioanalytical methods” (LRAM) is appointed as a control laboratory of Nuclear Regulatory Agency (NRA). As such the laboratory analyses gaseous and liquid releases of NPP for gamma, alpha and beta emitters.

Some methods for the determination of actinides have been developed to be applied to the samples – aerosol filters and water. The procedures include ashing, dissolution, precipitation, separation by anion-exchange resin, separation and purification by extraction chromatography and measurement by alpha spectrometry. Chemical recovery was determined by using tracers – ^{242}Pu (to calculate concentration of $^{239+240}$Pu) and ^{243}Am (for ^{241}Am). Alpha sources have been prepared by using two techniques: micro co-precipitation with Neodymium Fluoride and electroplating.

Determination of ^{90}Sr in water and aerosol filters – by use of adopted in-lab procedure with co-precipitation and separation techniques, extraction chromatography. Chemical recovery was obtained by using ICP-OES to calculate concentration of stable strontium. The concentration was measured by using liquid scintillation spectrometry.

Determination of ^{3}H concentration in technological water samples from NPP „Kozloduy” was based on the Standard: ISO 9698-1989 “Water quality – Determination of tritium concentration – liquid scintillation spectrometry”.

2. Investigation of the possibilities for improvement and expanding of the experimental measurements, on which is based the evaluation of the fluence through critical welds of the reactor vessels in NPP-”Kozloduy”

- Application of the adopted technique for determination of the specific activity of Nb-93m in activation detectors.
- Determination of specific activities of Mn-54 and Co-60 in activation detectors.
- Verification of the determined efficiencies with test source of Nb93m.
- Determination of the specific activity of activation detectors from units 5 and 6 of NPP ”Kozloduy”.

3. Radiological analysis of of ^{129}I, ^{99}Tc and ^{63}Ni radionuclides in environmental ground waters on the Radiana site, south of NPP “Kozloduy”.

In 2014, as a part of the National Strategy for Management of Spent Nuclear Fuel and Radioactive Waste by 2030, on the "Radiana" site near the NPP "Kozloduy", was made the first sod for the building of National Radioactive Waste Repository (NRWR). As a part of the initial stage, the environmental impact assessment (EIA) on the "Radiana" site should be made.

In the frame of the contract between THETA CONSULT Ltd. as the Employer and the Institute for Nuclear Research and Nuclear Energy of the Bulgarian Academy of Sciences as the Contractor and the contract subject being determination of some radionuclides - ^{129}I, ^{99}Tc and ^{63}Ni in environmental ground waters on the “Radiana” site, south of NPP “Kozloduy”.

According to first stage was developed a complex sequential procedure for determination of ^{129}I, ^{99}Tc and ^{63}Ni radionuclides in groundwater sample matrix. Ion-chromatography resins for separation and concentration of target radionuclides were used.

The measurements of sample aliquots were performed by using of two different measurement techniques – liquid scintillation counting and ICP-MS (without ^{63}Ni). Because of the long half-life of the nuclides ^{129}I (1.57 x 107 years) and ^{99}Tc (2.15 x 105 years) can be defined their mass concentration in aliquot by mass spectrometry with inductively coupled plasma (ICP-MS), and by the law of radioactive decay can recalculate their specific activity. ICP-MS was used to calculate the recovery of the radiochemistry procedure.

The mass spectrometry was perform by VARIAN 820-MS Mass Spectrometry System with quadrupole mass-spectrometer and fully digital detector with high concentration range, including innovative CRI-interface to remove polyatomic interferences. Low-background system for liquid scintillation analysis Tri-Carb^{R} 2700TR (made by Packard Instrument) has been used. The provided analysis was fast and reliable, according to evaluated data.

THE CYCLOTRON LABORATORY OF INRNE-BAS

HEAD OF LABORATORY: ASSOC. PROF. DR NIKOLAY GOUTEV

The Institute for Nuclear Research and Nuclear Energy (INRNE) at the Bulgarian Academy of Sciences (BAS) has been working since 2012 on the project "Cyclotron laboratory of INRNE-BAS". The project was launched in 2012 at the initiative of the Council of Ministers of the Republic of Bulgaria and the management of INRNE-BAS to solve a very old problem of the country - the lack of domestic production of short lived medical cyclotron radioisotopes, which has existed for decades despite repeated efforts of several generations of researchers from INRNE-BAS and the medical community to persuade the Government that such a center should be built in Bulgaria as was done a long time ago in the other Eastern European countries.

The project envisions a new cyclotron laboratory as a part of INRNE-BAS consisting of: a specialized building that meets the regulatory requirements in the field of radiation safety and GMP (good manufacturing practices) in the pharmaceutical industry; a bunker with a TR-24 cyclotron; a sector for applied research and development in radiopharmacy with enhanced educational functions; a sector for the production of 18F-FDG and, in the future, of other radiopharmaceuticals.

One of the main objectives of the project is within five years to allow for regular supply of 18F-FDG to 8 regional PET/CT center at a low price, providing "full cost recovery", with a small profit margin used to sustain the laboratory. This will enable more hospitals in Bulgaria to purchase new PET/CT equipment as well as to increase the throughput of the existing scanners. This will allow the examination of 16,000 patients a year in the regional PET/CT centers. The wider access to PET/CT will improve the health and extend the life of the patients suffering from cancer. The revenue from the sale of radioisotopes and radiopharmaceuticals will be fully reinvested in the research program and in the development of the laboratory. The availability of a production sector, meeting all modern regulatory GMP requirements will ensure high quality training of nuclear pharmacists and will close the chain from research – through R&D – to end products with applications in medicine.

It would have been practically impossible to start-up the project without the generous contributions of our first financial donors. For the purchase of the cyclotron and construction of the laboratory $3,000,000 USD were donated from the United States Department of Energy (DOE) and $2,000,000 USD from NPP "Kozloduy".

Figure 1. A photograph from the official launch ceremony of the project. In the presence of members of the Council of Ministers of the Republic of Bulgaria $3,000,000 USD were donated from the United States Department of Energy and $2,000,000 USD from NPP "Kozloduy".

In 2014 the project for a new cyclotron center was included in the updated "National Roadmap for Scientific Infrastructure" of Bulgaria. At the beginning of 2015 the project was identified as a priority of the Bulgarian-American relations in the field of science and education. For several years the management of INRNE-BAS has been actively working to insure further state support for the construction of the building of the cyclotron laboratory.

In 2014 INRNE-BAS completed successfully the public procurement tender for the cyclotron and signed a contract for the delivery of a TR-24 cyclotron, manufactured by the Canadian company ACSI. In 2014 and early 2015 payments of $3,120,000 USD were made under the contract by INRNE-BAS and the United States Department of Energy, demonstrating the strong commitment of both parties to the project.

The TR-24 cyclotron of INRNE-BAS, Figure 2, has the following characteristics: accelerates negatively charged hydrogen ions; variable energy of the proton beam; minimum energy of the proton beam of 15 MeV; maximum energy of the proton beam of

24 MeV; proton beam current of 400 μA, upgradeable to 1000 μA; simultaneous extraction of two proton beams; external CUSP ion source.

Figure 2: The TR-24 cyclotron of INRNE-BAS, under construction in the factory of ACSI, Vancouver, Canada.

The cyclotron parameters have been selected in such a way that in the next twenty years INRNE-BAS will be able to produce a wide range of radioisotopes with applications in medicine with a relatively low initial investment and moderate maintenance costs. At these proton energies and beam current it is possible to produce commercial quantities of radioisotopes with traditional and expected future applications in medicine as: PET radioisotopes - 18F, 124I, 64Cu, 68Ge/68Ga; SPECT radioisotopes - 123I, 111In, 67Ga, 99mTc; alpha-emitters for therapy - 225Ac/213Bi, 230U/226Th. Some part of the equipment for the production of radioisotopes will be designed and constructed in INRNE-BAS with the help of the Design and Production Workshop - Physics and will be sold on the international market subsequently.

SCIENTIFIC AND EXPERIMENTAL FACILITIES

NUCLEAR SCIENTIFIC EXPERIMENTAL AND EDUCATION CENTRE

HEAD: PROF. DSC KIRIL KREZHOV

During 2014 the staff of NSEEC was mostly involved in the maintenance of the facilities of the Research nuclear reactor IRT-Sofia and its associated laboratories and equipment in accordance with the requirements of normative documents concerning nuclear and radiation safety. Strict enforcement of safety measures was ensured through the implementation of the “Program for ensuring of nuclear and radiation safety of the shutdown nuclear reactor", specifically elaborated by the NSEEC staff in accordance with the recommendations and requirements of the IAEA and EURATOM, which was approved by the Director of INRNE and coordinated with the Bulgarian Nuclear Regulatory Agency (BNRA).

The control of the working environment and the radiological status at the IRT area was performed in accordance with the General Radiation Monitoring Program by comprising a set of technical and organizational resources and activities related to the implementation of the ALARA principle. Monitoring of the research reactor site and the auxiliary laboratories was accomplished through measuring, recording and evaluating of radiation dose rates, gamma, alpha and beta activities, volume activities, and mass activities. This provided early detection of radiation hazards and evaluation of eventual releases, as well as their consequences to the staff and the environment and served as a proof that the normative limits of allowed discharges were not reached. Monitoring of environment was performed at a net of pre-selected observation points, in which the quantity and distribution of effective doses and their loads were determined. The determination was based on taken samples, which were measured for total beta activity and radionuclide contents in air, water and in selected components of the environment. Particular detector systems are placed at selected locations of the reactor site.

The comprehensive long-term monitoring of the IRT area allows for obtaining accurate information for the typical levels and concentration ranges of various parameters including radiation level in the atmosphere and to get an unbiased assessment of the quality of workplace environment. The amount of radionuclides being introduced into the environment, if any, is very low; in majority of cases it is under the detection limits of measuring devices being used, generally demonstrating a high level of environmental safety in accordance with the requirements of existing legislation. The measured values for total beta activity in groundwater vary in a narrow range for all drill wells – from 0.25 to 0.49 $Bq.l^{-1}$. There are no significant variations in the content of beta radionuclides in precipitation water (rains and snow melts). The data obtained in 2014 range from 0.56 to 1.32 $Bq.l^{-1}$. The smallest values were registered on 05.03.2014, while the maximum was registered on 05.08.2014. There is a downward trend in the average annual concentration in the period 2011 - 2013: the mean value for 2011 is 1.26 $Bq.l^{-1}$, for 2012 - 1.04 $Bq.l^{-1}$, and for 2013 - 0.72 $Bq.l^{-1}$. The mean annual value obtained for 2014 is 0.98 $Bq.l^{-1}$. The content of beta emitters in soils fluctuates from 592 to 745 $Bq.kg^{-1}$ at the sampling point for the Reactor Equipment Storage and between 483 and 637 $Bq.kg^{-1}$ at the sampling point for the Gamma Irradiation Facility, while in plant samples it is from 98 to 137 $Bq.kg^{-1}$ in redwood (*Sequoiadendron giganteum*) and between 138 $Bq.kg^{-1}$ and 181 $Bq.kg^{-1}$ in acacia (*Robinia pseudoacacia*).

The results proved the absence of any anthropogenic impact in the IRT site boundaries; consequently there was no radiation exposure on residents of nearby Sofia districts.

Open door days for students from high schools and practical lectures for university students were organized (Fig.1). The NSEEC personnel presented to the groups of visitors the history of the IRT-Sofia research reactor and main fields of use in natural sciences, medicine and environment.

Interim stay were organized in the reactor control room, the radiation protection department and the radiochemistry laboratory Class I.

Fig.1. Introductory course with internship students from New Bulgarian University (left) and from Plovdiv University (right)

Participation in national projects:

1. Daily provision of data for gamma-radiation background from the reactor site to BNRA: http://www.bnra.bg/bg/emergency/radgamma_background/inrne.

The control of gamma background is performed continuously (around the clock) using an automated radiation monitoring system. The measurements are taken from six control points by a gamma detector (gamma radiation monitor GIM-204), which is mounted 2 meters above the ground. In 2014, the results obtained for the level of gamma background for the territory of NSEEC ranged between 0.09 μSv/h and 0.135 μSv/h.

2. Contract with the Institute of Plant Physiology and Genetics – Bulgarian Academy of Sciences: “Leakage control of the sources of ionizing radiation incorporated in the Gamma irradiation facility GOU-3M by taking smears and spectrometric analysis of these smears for determination of technogenic radionuclides”.

3. Contract with NPP Kozloduy - „Validation of neutron fluence in the reactor pressure vessels of Units 5 and 6 of NPP Kozloduy“ (2013-2015).

4. Written translation from Russian into Bulgarian language of technical documentation developed by OAO "TVEL" in the frame of the contract with "NPP Kozloduy" on "Development of advanced nuclear fuel cycle and justification of safe operation of Units 5 and 6 of Kozloduy NPP PLC with modified nuclear fuel at power level of 3120 MW".

Participation in international projects:

1. Project 11c – „Evaluation of the material Backlog and Radiological Inventory of KNPP Units 1 to 4” - Grant from the Kozloduy International Decommissioning Support Fund (KIDSF), administered by the European Bank for Reconstruction and Development – in cooperation with Specialus Montazas NTP, Visaginas, Litva;

2. Project “Establishment of a Regional Center of Competence for VVER Technology and Nuclear Applications” - funded by the Framework 7 Programme of the

European Commission - FP7-Fission-2011, CORONA Project, Grant Agreement № 295999 – (2011-2014);

3. Project „Danube WATER integrated management (WATER)";
4. Project EMERSYS – "Toward an integrated, joint cross-border detection system and harmonized rapid responses procedures to chemical, biological, radiological and nuclear emergencies".

In 2014, members of NSEEC published 8 scientific papers in national and international journals (7 articles in journals with Impact Factor), 3 papers were accepted for publications and 5 articles were published in Proceedings of national and international conferences. A total of new 28 citations were spotted.

BASIC ENVIRONMENTAL OBSERVATORY (BEO) MOUSSA

HEAD: ASSOC. PROF. DR CHRISTO ANGELOV

The Moussala Basic Environmental Observatory (BEO) is situated at the highest peak of the Balkan Peninsula – Moussala (2925.4 m a.s.l., 42º10`45``N, 23º35`07``E) in Rila Mountain – the central part of the Bulgarian southern mountain area. Moussala Peak's unique geographical location (the boundary of the lower troposphere) allows one, in addition to the traditional research related to cosmic rays, to conduct research related to global climate change, transboundary pollution transport, possible correlations of cosmic ray intensity with atmospheric parameters, etc.

In 2014, the team of Moussala BEO has continued the research work in the framework of the FP7 project ACTRIS "Aerosols, Clouds, Trace Gases Infrastructure" (2011-2015). Data for aerosol measurements have been regularly sent to the Norwegian Institute for Air Research (NILU), Norway, and the National Oceanic and Atmospheric Administration (NOAA), the USA. Under a Letter of Intent signed with RECETOX, Masaryk University, Brno, the Czech Republic, a set of filters were prepared in the BEO under a five-year project for investigating the distribution of persistent organic pollutants (POPs) over Europe. In real time, we have continued to send gamma background and meteorological data to the European Commission through the Joint Research Centre (JRC, Ispra), Italy. On a daily basis, gamma background data have been placed at the disposal of the Nuclear Regulatory Agency (NRA), Sofia. The muon telescope and the SEVAN (Space Environmental Viewing and Analysis) Network (collaboration with Aragatz High-Mountain Observatory, Armenia), working in a continuous mode, gave us opportunity to investigate variations in the cosmic ray intensity. The data thus obtained have been transferred and analyzed. On-line data and detailed information about Moussala BEO are available at:

http://beo-db.inrne.bas.bg/moussala/

On Dec. 1, 2013, the BACCHUS (Impact of Biogenic versus Anthropogenic Emissions on Clouds and Climate) project was launched where INRNE with Moussala BEO is a partner together with 20 leading scientific European centers in climate change studies.

In 2014, Moussala BEO was re-certified by IQNET for the ISO 9001:2008 and ISO 14001:2004 standards.

2014 RESULTS:

A Na(I) spectrometer for on-line measurement of the gamma-rays spectrum in air has functioned continuously since the beginning of 2013. A longer monitoring period, ~2 – 3 years, and a comparison with the data from other devices at BEO-Moussala will help to clarify and find aan explanation of the phenomena observed. The program for measuring the radioactivity of air aerosols at Moussala Peak has continued for more than eight years. The article "Tracking of airborne radionuclides from the damaged Fukushima Dai-Ichi nuclear reactors by European networks", in which our colleague Dr. Ilia Penev is a co-author, has been cited more than 140 times since September 2011.

The aerosol measurements at the BEO Moussala station showed that the site lies above the Planetary Boundary Layer for about a half of the year: from autumn to early spring (September to February), (Fig.1). Changes in the situation occur in March, when the station is found to be below the PBL, and in August, when it is above it. The months from May to August are typical when the daily variation are influenced by local convection processes of air masses with a high concentration of particles, especially in the period from noon until evening, with a maximum in July and August. During the spring and summer months, when a strong influence of convection processes is present, a time window exists from midnight to morning which enables one to perform measurements under the conditions of the lower free troposphere.

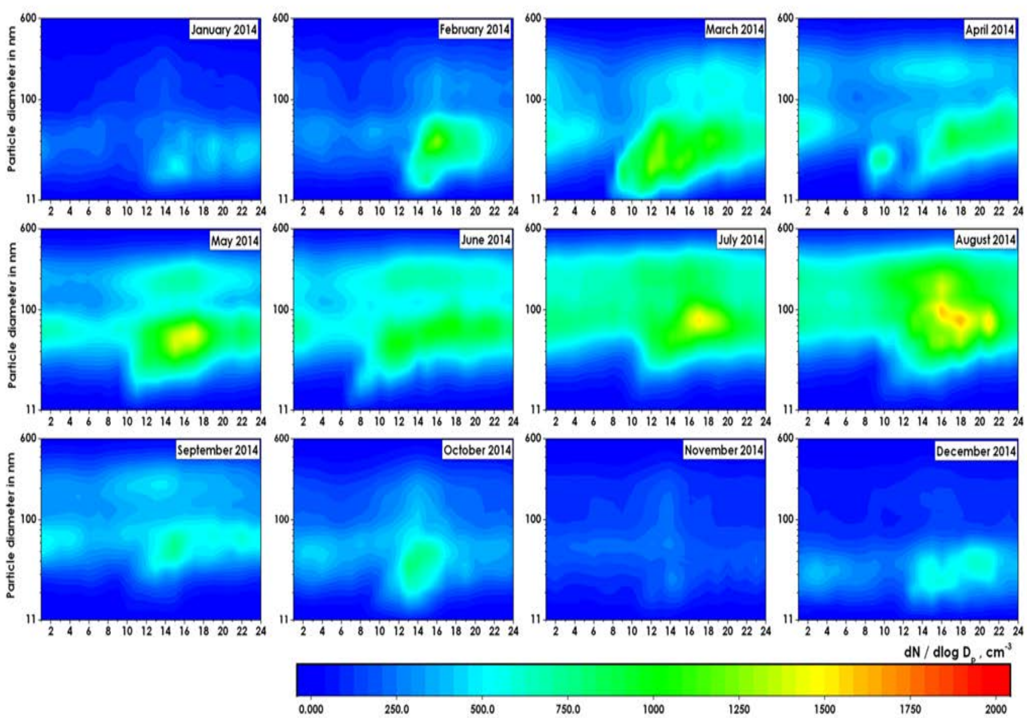


Fig.1. *Monthly mean daily variation of particle number concentration in the size range from 11 to 600 nm at Moussala site for the period January 2014 to December 2014, represented by a color code in the range from 0 to 2000 dN/dlogDpcm-3 particles per size class from blue to red*

During the MONET field campaign, conducted in the vicinity of Moussala Peak in the period March 2009 – March 2013, a large amount of data were collected on the atmospheric levels of POPs, (Fig.2). POPs are a major object of monitoring as they are toxic and remain intact in the environment for long periods of time. Because of their possible trans-boundary transport and accumulation, which was detected in organisms across vast geographical regions, they were classified as substances which should be placed under control and monitored.

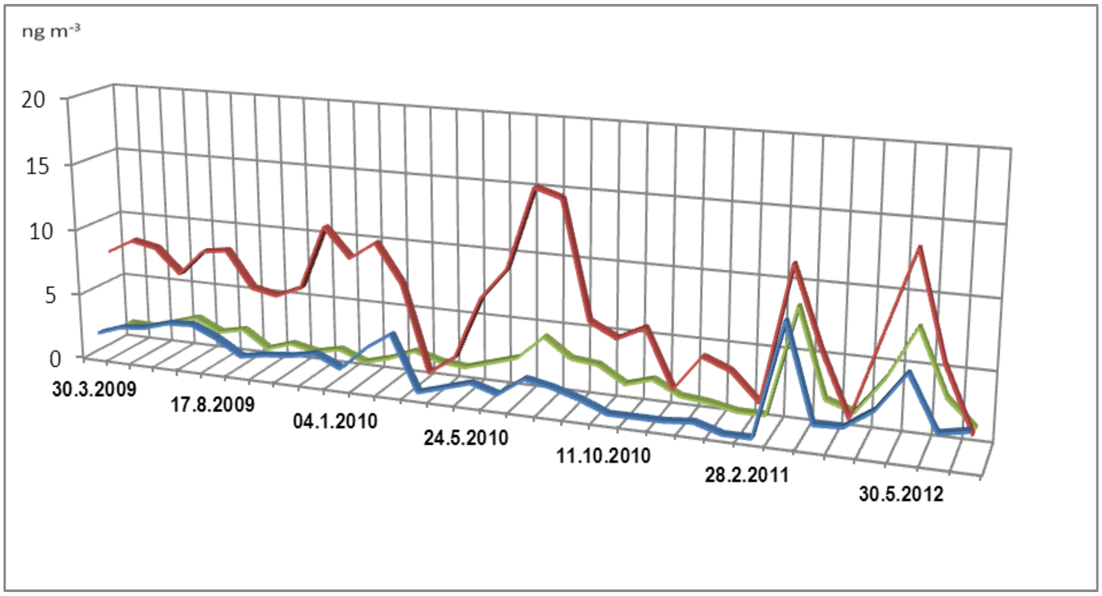


Fig.2. *Spatio-temporal deposition of persistent organic pollutants (PCBs(blue), HCHs(red), and DDXs(green)) at high mountain EMEP station BEO Moussala in the period March 2009 - May 2012, (ng m*$^{-3}$*)*

During the visit of Dr. L. Ries, station manager of the GAW station UFS-Zugspitze, Germany, to the INRNE in 2013, INRNE-BAS and Moussala BEO were invited to take part as associated partner in the project VAO-II (Virtual Alpine Observatories – II).

VAO is a European networking research project in the field of climate variability. It joins 16 institutes from Germany, Switzerland, Austria, Italy and other European countries with some of the high mountain observatories (Sonnblick – Austria, Ungfraujoch-Gornegrad, Switzerland) providing Alpine atmospheric data. VAO-II (from 2013 to 2016) is the second phase of the project where the main object is unifying the measurements of the high-mountain observatories applying common procedures for data acquisition and data storage.

Taking part in VAO II is of high importance because the possibilities of Moussala BEO are thus appreciated by the wide scientific community. Moussala BEO has had long years of fruitful cooperation with the main partner in this project, UFS – Zugspitze, during and after the HIMONTONET and BEOBAL FP5 and FP6 projects. The foundations of this cooperation were laid by the late Prof. J. Stamenov (1940 – 2014), former Director of the INRNE, and Dr. W. Fricke, former Director of the Hochen Peissenberg GAW station – Germany.

Fig.3. *Measuring system ECOPHYSICS 770*

In 2014, under the framework of VAO II, the INRNE received a donation from UFS – Zugspitze, namely, the ECOPHYSICS (CRANOx) 770 NOx measuring system (Fig.3), with consumables, a calibration gas volume and spare parts for two years. The CRANOx system, consisting of a CLD 770AL gas analyzer with a ppt (points per trillion) accuracy, a PLC 760 MH photolytic converter and an Environics S100B automated generator for calibrating gas mixtures replaced the AC32M Environement NOx analyser, which had been switched off long before due to the lack of spare parts and consumables. From 18.10.2014 to 25.10.2014, Moussala BEO was visited by Ralf Sohmer, researcher at UFS, with the mission of installing and initial training, which was still another expression of the German partner's good will of supporting the work of Moussala BEO.

In "Ecotoxicology Group" during 2014 the monitoring of water and terrestrial ecosystems at Rila mountain area (Ice Lake, Moussaka Lake etc.) and North-West Bulgaria was carried out by measurements of the content of chemical elements, radioactivity (^{3}H, ^{137}Cs,^{40}K etc.) and physicochemical indices investigated in water reservoirs. Some mineral waters from these regions are investigated by the methods of water spectra analysis. The results correspond with the data from previous years.

DEPARTMENTS

<u>**ASSOCIATION EURATOM – INRNE**</u>

HEAD: PROF. DSC TROYO TROEV

ITER is the most ambitious scientific project in the world. It is designed to produce approximately 550 megawatts of fusion power sustained for 400 seconds. ITER is a global project to build and operate an experimental reactor with the aim of demonstrating the scientific and technological feasibility of fusion energy for peaceful purposes. Its successful accomplishment would establish whether fusion can become a major sustainable energy source contributing to the EU's strategy for the long term security in the supply of energy. The ITER project should be followed by a demonstration reactor on the path towards the commercial exploitation of fusion power. ITER will be the first fusion experiment with an output power higher than the input power. It is expected to produce power in the hundreds of megawatts, and emit 10 times more energy than it puts in. Successful operation of a ‘Demonstration Reactor’ (DEMO), capable of generating net electricity and operating with a closed fuel-cycle, is a key step in the development of economic fusion power. The recent EU Fusion Roadmap highlights inter alia also to the ‘Materials Mission’ to develop nuclear-hardened structural, plasma facing (PF) and high-heat flux (HHF) materials for DEMO’s in-vessel components, especially the Breeding Blankets and Divertor.

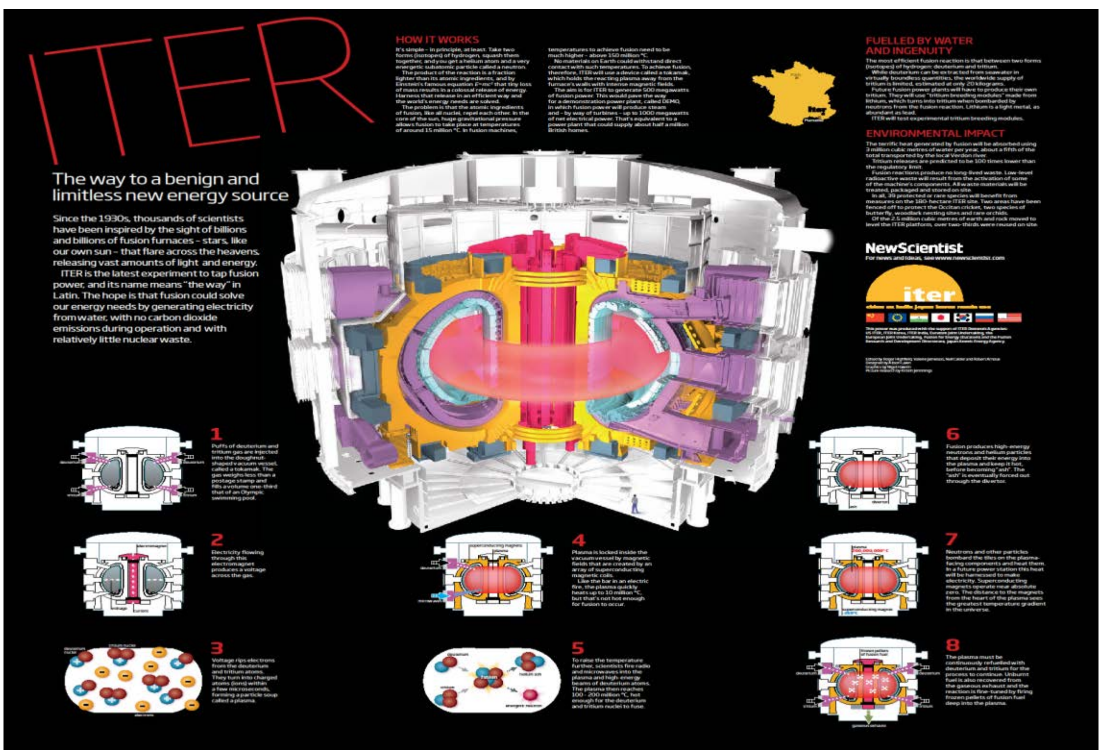


Figure 1. ITER

Sitting ITER in the European Union is an honor for the European fusion community. One of the main challenges for fusion reactors is the compatibility between reactor-grade plasma and the materials facing the plasma - the "First Wall". JET and most current tokamaks use carbon composite (CFC) tiles for the First Wall. The ITER materials tests with fusion neutron ('14MeV'), spectrum before DEMO design finalization is essential to Fusion Materials development. To do this in a timely manner requires deployment of a ≥30 dpa (steels) 14MeV testing capability by 2026. The technical possibilities for early deployment, based on variations and acceleration of the IFMIF programme are assessed.

In October 2014 in Brussels has been signed the CONSORTIUM AGREEMENT - EUROFUSION for the period of 2014-2020.


EUROfusion

'Synergy today for the energy of tomorrow'

The launch of EUROfusion represents a major milestone for energy research in Europe.

On 9 October 2014 at the Bibliothèque Solvay in Brussels, the EUROfusion consortium members and the European Commission came together to acknowledge and celebrate the signature of the

'European Fusion Joint Programme'.

This unprecedented collaboration demonstrates the shared ambition to provide a long-term and sustainable solution for Europe's energy challenge.

Signed and presented to the EUROfusion partners

Robert-Jan Smits
On behalf of the European Commission

Sibylle Günter
On behalf of the EUROfusion consortium

EUROfusion

Figure 2.

Figure 3. ***Robert – Jan Smits, Director – General of DG Research and Innovation and Head of Research Units of European Fusion Associations during the***

signature of Grant Agreement between the EUROFUSION and European Commission in Brussels 2014.

The ITER design comprises beryllium-clad First Wall in the main chamber, while use of carbon tiles is limited to the region where the edge plasma is deflected on to the wall ”divertor strike points” the tungsten tiles are to be used on the divertor. The lifetime of the wall will be studied with ITER-relevant power loading provided by increased heating due to Neutral Beam Enhancement Project. Tungsten is considered the long-term front runner as a material for fusion reactors. As fusion is a nuclear process the fusion power plant structure will become radioactive – by the action of the energetic fusion neutrons on material surfaces. However, this activation decays rapidly and the time span before it can be re-used and handled can be minimized to around 50 years by careful selection of low-activation materials. During the operation of ITER, a parallel materials testing programmed will be undertaken – developing and accessing the materials needed for a power plant.

The EURATOM-INRNE Fusion Association accomplished a number of activities in science and technology which are reported in the annual WP-2014 reports. Progress has been achieved and has also resulted in the increased research experience. The milestones are focused on the pragmatic approach to fusion energy. The basic research is address to several areas of the fundamental understanding which is required to predict the integrated plasma behaviour in ITER and DEMO according to the roadmap of the fusion scientific community.

The Association EUROFUSION-INRNE during the 2014 has taken part in the fusion developments under Grant Agreement in the following tasks.

1. Provision of support to the advancement of the ITER Physics Basis by two tasks:

1.2 Langmuir probe measurements of the plasma potential and EEDF for edge turbulence diagnostics at COMPASS tokamak.

2. Development of plasma auxiliary systems;

2.1 Heating and current drive systems by three tasks:

2.1.1 Development of volume-production based RF sources of negative ions.

2.2.1 Probe measurements of the plasma parameters in divertor area of COMPASS tokamak.

2.2.2 Investigation of non-thermal electrons in the boundary region of the TJII stellator from IV Langmuir probe characteristics.

3. Development of concept improvements and advances in fundamental understanding of fusion plasmas by two tasks:

3.4. Theory and modelling; Material computer modelling needs to play an increasing role in the development of fusion materials.

3.4.1 Model predictions of accumulated defects in Fe and Fe+C, W and W+C. Atomistic calculations of positron lifetime in defects of Fe, Fe+C, W and W+C.

4. Emerging technologies one task:

4.4. Development of HT superconductors for DEMO:

4.4.1 Preparation and study of iron-based superconducting materials.

5.2. Career development fellowships

The Association EURATOM-INRNE during 2014 participates in different activities under different frames made the best efforts to maintain a very active attitude in all possible aspects of fusion science and engineering.

In the framework of the European Fusion Programme WP-2014 the Association EURATOM-INRNE has motivated a strong collaborative programme together with the Fusion Association in Europe and Japan.

ANALYSIS OF RADIOACTIVE AND NUCLEAR MATERIALS OF ILLEGAL ORIGIN
(NUCLEAR FORENSICS)

HEAD: ASSOC. PROF. DR. HRISTO PROTOHRISTOV

The Department is a specialized unit organized for scientific-technical expert support of state authorities: Bulgarian Nuclear Regulatory Agency (BNRA), Ministries and Law enforcement organizations: Police, Border police and Custom control, Investigation and Prosecution etc. in identification and analysis of radioactive and nuclear materials from illicit trafficking and of unknown origin, as well as, in cases of radiation and nuclear emergency events. Special attention is devoted to development and implementation of methods and specialized education in the field of prevention of illicit trafficking of radioactive sources and nuclear materials, transfer of nuclear technologies and know-how, and counterproliferation of dual use commodities with nuclear application.

The Department maintains 24h/7d redness with equipment and personnel for remote operation of mobile high-resolution gamma-ray spectrometry according to the National action plan in case of radiological or nuclear accident.

During the year, nuclear forensic expertises were prepared for prosecution cases of illicit traffic of sources of ionizing radiation. In one case, sized strong radioactive geological samples transported illegally form Africa were investigated (Fig.1). Gamma-ray spectra were measured and uranium with natural isotope ratios was identified in the samples. The element composition of the different minerals was studies by means of energy dispersive X-ray fluorescence, where also high quantity of uranium and other associated metals were detected.

Fig. 1. Illegally transported uranium minerals analyzed in the Department

To improve the qualification of INRNE-BAS personnel in the field of radiological and nuclear accidents, three responsible senior experts from the institute participated the course: “Weapons of Mass destruction (WMD) Crisis Incident Management” organized by US Defense Threat Reduction Agency, Federal Bureau of Investigation and Federal Emergency Management Agency. All received certificate for planning and management in WMD incident.

For the National Service for Protection a lecture and discussion on radioactive and radiotoxic agents - types, detection, analysis and prevention was organized in the Qualification and Training Centre for Specialized Education of INRNE-BAS

During the year, the Department took part in the realization of the international project EMERSYS “Toward an integrated, joint cross-border detection system and harmonized rapid response procedures to chemical, biological, radiological and nuclear emergencies”, MIS ETC Code No 774. Two experts from the Department where qualified for work with the analytical equipment for detection of CBRN-agents. The equipment is incorporated in the specialized mobile laboratory delivered in INRNE-BAS in the framework of the Project. Two senior researchers from the Department were active as lecturers on analytical equipment and chemical agents in the EMERSYS courses organized for officers of Ministry of Interior Chief Directorate Fire Safety and Civil Protection.

The database for geolocation of natural radioactive materials has been extended with element and isotope composition of uranium ores from closed uranium mines in Bulgaria, as well as, of geological samples from minerals from rich uranium deposits in Tanzania, Africa.

The Department contributes with lectures and practical exercise in nuclear forensics incorporated in the courses of the INRNE-BAS Qualification and Training Centre for Specialized Education (TCSE). The TCSE organizes initial and supporting education for work in radioactive environment for officers of General Directorate Border Police, inspectors of National Custom Agency and for X-ray baggage scanner operator of the airports in Sofia, Plovdiv, Varna and Burgas. In addition to the general program of the course, the above personnel is educated and trained in the field of illicit traffic of radioactive and nuclear materials and their malevolent use.

NUCLEAR RADIATION MEASUREMENT CENTER

LABORATORY: SEMICONDUCTOR DETECTORS

HEAD: ASSOC. PROF. DR MIKHAIL MIKHAILOV

The laboratory works in the field of detector physics research, detector technology, and detector-associated electronics. Its supports the experiments conducted in the Institute for Nuclear Research and Nuclear Energy with methodological and technical assistance where semiconductor detectors of alpha, beta, gamma rays, and neutrons are used. Gamma and X-ray detectors maintenance and repair are part of its work. The laboratory is the only place in Bulgaria where this can be done.

During 2014 the spectroscopy characteristics of five HPGe detectors, property of different national organizations and INRNE-BAS have been restored and tested. The characteristics of other three spectrometers have been checked.

A NaI(Tl) scintillation detector with silicon photomultiplier readout has been constructed and tested. The results obtained show FWHM better than 16 %. This is reasonably good for the scintillator and silicon photomultiplier used.

EUROPEAN PROJECTS

EUROPEAN PROJECTS DEPARTMENT – MORE 14 YEARS ACTIVITIES

HEAD: ASSIST. PROF. DR. BOYKO VACHEV

I. Implementation and development of projects

Department of European projects (DEP) was established in the beginning of 2000, more 2,5 years before 30-th INRNE anniversary. During its above 14 year history the DEP is acting by direct governance of the INRNE Director.

In 2014 the responsible for the European Projects of INRNE BAS (EP) participated in final reporting and financial completing of project BLACKSEAHAZNET and in the development of initial conception proposal for INRNE centre of excellence project proposal for Ministry of education and science. Consultations were also provided for projects under the Seventh Framework Programme, etc.

Results of the participation in the 7th Framework programme and the place of INRNE

For the period 2007 – 2014 INRNE submitted around **58** projects under the 7FP, EURATOM, JRC, INTERREG programmes, etc.

Twenty eight (28) projects or 48% were approved (from received definitive estimation), including **11** under EURATOM, **6** under JRC, **5** under “Research Infrastructure”**, 1** under “Marie Curie” programme, **1 –** ERA NET, **3** COST projects; **22** (**38%**) were not approved; **8** (**14%**) were approved (above the barrier) but were not funded due to lack of financial resources.

In more details projects are:

1 Network of excellence (NoE) SARNET2 (Network of Excellence for a Sustainable Integration of European Research on Severe Accident Phenomenology and Management – Phase 2)***; Large scale integrated project (LS IP) NURISP*** (Numerical coupling of safety related phenomena), as well as projects ***NURESAFE*** (NUCLEAR REACTOR SAFETY SIMULATION PLATFORM), Collaborative project и ***CESAM*** (Code for European Severe Accidents Management) Collaborative project***; 1 Collaborative projects BACCHUS*** (Impact of Biogenic versus Anthropogenic emissions on Clouds and Climate:

towards a Holistic UnderStanding), ***2 Coordinating and Support Actions ASAMPSA_E (***Advanced Safety Assessment Methodologies: Extended PSA ***), ARCADIA (***Assesment of Rergional Capability for New Reactor Development throw Integrated Approach***), 5*** *Research infrastructure projects **(RI)*** ***AIDA*** (Advanced European Infrastructures for Detectors at Accelerators)***, ENSAR*** (European Nuclear Science and Application Research), ***SPIRAL2PP, ACTRIS*** (Aerosols, Clouds, and Trace gases Research Infrastructure Network)***, NENEART*** (NEolitic Nephrite ARTefacts: ***CHARISMA*** "Cultural Heritage Advanced Research Infrastructure: Synergy for a multidisciplinary Approach to Conservation/Restauration"); ***6*** *projects with* ***Joint research centre of EC (JRC)*****:** Neutron induced cross section measurements and evaluation in the resonance region on isotopes of hafnium for advanced reactor safety**;** Study on the verification of the TRANSURANUS code for nuclear fuel used in Bulgaria**;** EURDEP and ECURIE databases and systems и ***3*** *projects* ***EUFRAT*** (European Facilities for Innovative Reactor and Trasmutation Neutron Data), International Access to Experimental Facilities***; 2 EURATOM*** *projects:* Modelling predictions of the point defects and dislocations in non-irradiated and irradiated first wall materials, containing helium; Modelling of irradiation effects in materials due to neutron and ion radiation damaging*;* Neutronics analyses of Liquid-Cooled Lithium-Lead TBM in ITER and of Liquid-cooled lithium-lead blanket for DEMO, ***CORONA*** **(**Establishment of a Regional Center of Competence for VVER Technology and Nuclear Applications), ***NEWLANCER*** **(**New Member States Linking for an AdvaNced Cohesion in Euratom Research); ***1 ERA-NET NuPNET*** (ERANET for Nuclear Physics Infrastructures)***; 1 "Marie Curie"IRSES BlackSeaHazNet*** (Complex Research of Earthquake's Forecasting Possibilities, Seismicity and Climate Change Correlations)***,* 3 COST projects - *The String Theory Universe, SIMUFER (***Domain Committee: Materials, Physical & Nanosciences). ***NewCompStar (***Exploring fundamental physics with compact stars)

Success rate of INRNE European projects
5-th Framework Programme of EC ≈ **50%**
6-th Framework Programme of EC ≈ **62%**
7-th Framework Programme of EC ≈ **48%**
Horizon 2020 of EC (current rate) ≈ **43%**

The positive trend is continuation in FP7 the key projects from FP6, start of two new EURATM projects , also gaining a **COST project. The analogical trend is presented from the beginning of Horizon2020 (AIDA-2, CORONA-II).**

During 2014 have been submitted 7 Horizon 2020 projects (4 EURATOM, 1 MSCP, 1 COST and 1 Infrastructure), 3 have been accepted and 2 new projects started.

II. Information and methodological support activities

We participated in information days, workshops and other events, organized by the Ministry of Education and Science, the Bulgarian Academy of Sciences (BAS) and other state and non-governmental organizations (NGOs). The main Internet websites of the European Commission and MES are followed up on a regular basis.

As a result of a formal approach nine missed INRNE projects (6 with JRC, 1 of Research infrastructure, 1 INRNE-EURATOM Association plus 1 distributed for other

BAS institute) have been recognized in the ranking of BAS FP7 European projects commission. After strong discussion to the INRNE have been returned back all missed projects and added large amount to INRNE and BAS European projects balance.

III. Relations with European, international, partner and local institutions and organizations

A close connection with EC REA is preserved and further development of collaboration with Ukrainian embassy and other neighbor countries diplomatic missions has been developed.

INRNE hosted and co-organised the ERA monitoring mission in April, 2014 for IRSES MSCP projects. Around 15 projects in near all fields of science and with all continents collaborations have been presented.

IV. Science communication

Exhibitions, celebrations and other events

INRNE was presented by a poster named "The nuclear science for the progress", in which different aspects of the Institute's activities were illustrated at the exhibition "BAS-science for the public and state benefit".

V. Participation in the attestation campaign of BAS and the attestation of the researchers in INRNE BAS (2014) - the DEP participated actively in the campaign for INRNE BAS attestation: the responsible for European projects of INRNE BAS ranked among first 30-th in the general ranking of 110 researchers.

VI. Main academic achievements of DEP for its more than 14 year's history

1. Contribution to BEO Centre of Excellence and BEO IEC (Integrated Environmental Centre) establishment and development

2. Contribution to INRNE Indicative projects – INRNE-JRC NUSES project and 2 CoE projects - HIMONTONET and BEOBAL http://www.beo.inrne.bas.bg/dep/EU_PROJECTS/NUSES/NUSES_MENU.html http://www.beo.inrne.bas.bg/HIMONTONET.htm http://www.beo.inrne.bas.bg/BEOBAL.htm

3. Conference – Informational days as a new form of science communication http://www.beo.inrne.bas.bg/dep/EU_PROJECTS/NUSES/NUSES_MENU.html http://www.beo.inrne.bas.bg/BEOBAL/BEOBAL_Conference-Informational_Days.htm

4. Contribution to BlackSeaHazNet MCA IRSES FP7 project – the first big European project, coordinated by INRNE BAS

5. Ministry of Education and Science, Republic of Bulgaria Award to INRNE BAS. On 31st of January 2007 the Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, was awarded the first prize for the most active scientific research team of the Sixth Framework Programme of the European Commission

6. Science Communication Activities, especially exhibitions and conference events

VII. Guidelines and tasks for 2015 also in the context of Horizon 2020 Programme

Based on more 14 years European projects history achievements, best practice in leading European research organisations, INRNE BAS management programme and research priorities main National and European scientific and technological goals I propose to reorganise and enhance projects activity as following (*see report to the Since council of INRNE from 10.11.2011*):

A. Centralisation of INRNE BAS projects activity: 1. Optimal standardization of project activities; 2. Widening the European projects activity – including all types of projects; 3. Development of internal projects data base, including specific documents and instructions; 4. Improvement and stimulation of Institute mutual exchange of experience and good practice among project teams and colleagues personally

B. Covering and closing of full life cycle of different kind of projects: 1. Strategic Analysis and Planning. Objectives and Criteria System. Diversification Potential for Partnership ad Funding Information; 2. Lobbing for single projects or specific thematic; 3. Ideas Generation; 4. Project outlining and writing. Budgeting; 5. Negotiation. Juridical aspects; 6. Project Execution. Participation in management in the frame of available resources; 7. Project Reporting. Budget and Finances. Auditing; 8. Project Results Dissemination and Implementation. Science and Technology Communication.

C. Improving of the potential and organizational structure of European projects activity in the frame of available INRNE BAS resources

D. All these will lead to and serve for: 1. Revenue increasing (more projects, more expensive projects, best “benefit– cost” ratio, ect.); 2. Decreasing of expenses (including due to better success rate, activities standardization); 3. Enhancement of INRNE BAS researchers project culture; 4. Improvement of quality of scientific, technological and educational (qualification) product of INRNE BAS (by synergy effect, increasing of leading role of Institute, know – how transfer, etc.).

BUREAU “CERN”

HEAD: ASSIST. PROF. DR. BOYKO VACHEV

The “Bureau CERN” is a separate department in INRNE BAS. It was organized from the end of 2000 to fulfil the functions of the ILO (Industrial Liaison Officer) according to the regulations of CERN. The “Bureau CERN” receives all inquiries, which the European Organization for Nuclear Research sends to industrial companies of its member states. In case that the Bureau CERN finds potential bidder(s) among the Bulgarian companies, it forwards these inquiries to them. It also consults the Bulgarian companies about the requirements and the internal rules of CERN.

Assist.Prof. Dr. Boyko Vachev was appointed as head of Bureau CERN by an order of the Director of INRNE BAS from middle of 2010 and is ILO for Bulgaria. Before the Bureau CERN was headed by Dr. Ivan Geshkov.

The results of the Bureau activity since its foundation (until the end of 2014) are as follows: Total number of inquiries at the “Market Survey” stage received in the Bureau CERN **– 545;** Number of various inquiries at the “Market Survey” stage sent by the Bureau to Bulgarian enterprises **– 230;** Number of enterprises that have received inquiries **– 314;** Classification of the sent inquiries according to “Cost Range”: Cost Range A – below 750 kCHF **– 89,** Cost Range B – from 750 kCHF to 5MCH **– 97,** Cost Range C – from 5 MCHF to 10 MCHF - **27,** Cost Range D – more than 10 MCHF –

17, Number of inquiries at the “Invitation to Tender” stage received by Bureau CERN – **620.**

In 2014 “Bureau CERN” received **128** inquiries (**59** market surveys and **69** invitations for tender). In accordance with their “Cost Range” the market surveys are classified as follows: Cost Range A – below 750 kCHF – **21;** Cost Range B – from 750 kCHF to 5MCHF – **22;** Cost Range C – from 5 MCHF to 10 MCHF – **7;** Cost Range D – more than 10 MCHF – **9.**

Invitation for tender received **11** Bulgarian firms totally **30** times for **21** tenders.

For the period Jan 1996 – Jan 2015 the Bulgarian enterprises received orders from CERN with a total value exceeding 17 000 000CHF. These enterprises are in the area of engineering (especially heavy machine building), electronics and information technologies, industrial services and construction. In this way the return of funds from membership dues from the participation in CERN auctions is more than 40% (see Figure 1 and 2 below).

Four years after “Bulgarian Industry and CERN” workshop organized on September 28th 2010 **in cooperation between CERN and INRNE BAS under the auspices of the Ministry of Economy, Energy and Tourism of the Republic of Bulgaria continues the positive trend to increase BG CERN industrial activity. Bulgaria is paid 50% of the membership fees in CERN for 2015 before end of 2014.**

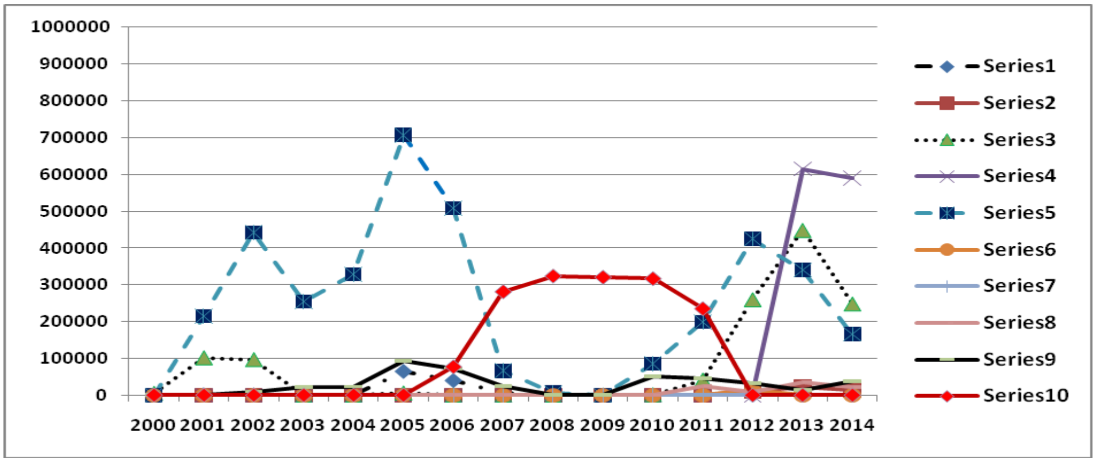
Below are presented Figure 1 and Figure 2, based on 15 years official data of CERN FC reports on purchasing. Let we make a short analysis.

The very positive trend is demonstrating last 4 years - 2012 and especially 2013 and 2014. It has its reasons in the deepening of the economical crises, partially as result from the 2010 BG – CERN industrial seminar and Bureau CERN activities.

Concerning the activities of 2014 we concentrated our efforts on contracts of type not presented before 2013 (as type 4 – *Computers* ...) and traditional industry production, first of all construction and civil engineering. The analogical tactic will be followed in 2015.

The results for 2013 **show near 2 times increase – up to 1476000CHF** of Payments and Outstanding commitments in 2013 for Supplies (Excluding visiting research teams and collaborations). The volume of contracts in 2013 and 2014 is not only **the first in ranking for 13 years** and **first time for two years above 1 000000CHF.**

Dynamics of BG CERN Industrial Supply and Industrial Service contracts 2000-2014 Figure 1
by types of Industrial Supply and Industrial Service (in CHF)

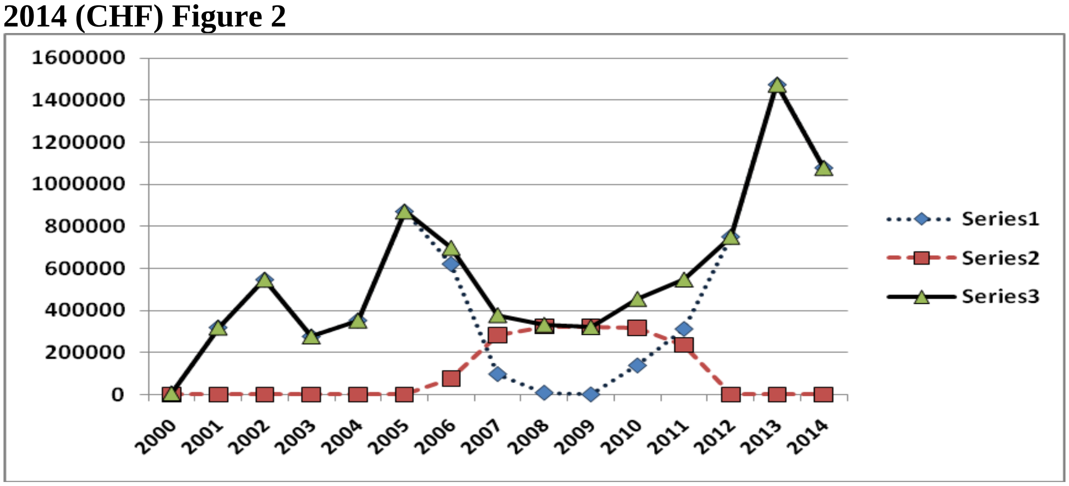


Legend of Activity Codes

1. Civil engineering and buildings
2. Electrical engineering and energy
3. Electronics (including radiofrequency equipment)
4. Computer systems and communicat ion, including rental and maintenance
5. Mechanical structures - Supplies & manufacturing techniques
6. Vacuum and low-temperature technology
7. Particle detectors
8. Miscellaneous (insurances, photoequipm., gases, vehicles, petrol, tools, furniture, office supplies, publications)
9. Design studies - Miscellaneous supplies

ISer – Industrial Service

Dynamics of BG CERN Industrial Supply and Industrial Service contracts 2000-2014 (CHF) Figure 2



For **2014 Industrial return per order and contract range for supplies of various amounts** (Excluding visiting research teams and collaborations) **Bulgaria has leading position for orders/contracts** a)<= 10kCHF, b)between 10KCHF and 50kCHF, c) between 200kCHF and 750kCHF and d)>750kCHF with industrial return respectively: a) **1,61**; b) **1,74**; c) **1,51** and d) **3,44**. In overall ranking it gives to Bulgaria respectively:

4-th place (after CH, SB and FR); **2-nd place** (after CH), **3-d place** (after CH and PL) and **1-st place** (before CH).

Bureau CERN participated actively in organising in INRNE BAS of the civil engineering meeting with experts of CERN Mr Luigi Scibile and Ms Lisa Bellini de Victor in December 2013. The second meeting in this field has made last year - a detail analysis of Bureau CERN activity since 2000 has been developed and presented by head of bureau.

A special analytical material and announce for the electricity supply tender has been prepared for the official visit of the President of Republic of Bulgaria Mr. Rosen Plevneliev by request of the Ministry of Education and Science.

Bureau CERN participated actively directly or indirectly in all meeting of new established Commission CERN of Ministry of Education and Science.

A project for celebration of 60-th Anniversary of CERN and 15-years of Bulgarian membership has been developed – it will be realized together by Institute of Nuclear Research and Nuclear Energy with National Archaeological Institute with Museum of Bulgarian Academy of Sciences.

As a result of systematic efforts of Bureau CERN, INRNE BAS, with governmental support, mainly also of Bulgarian business, supported by other colleagues working with/in CERN, and crucial CERN procurement support, the return of Bulgarian investment in CERN measured as volume of industrial supply contracts increased many times: The total volume of executed contracts in 2014 in comparison with 2010 increased **near 2,5 times** (see table below).

The return coefficient for industrial supply (one of the most important indicators for CERN member states) increased in 2014 in comparison with 2010 more then 7 times (from 0,16 to 1,18) (see table below)

Bulgaria preserve for second year 4-th place in ranking by return coefficient for industrial supply after Switzerland and Hungary and just after France (they have respectively 3,73, 1,66, 1,57) and before Italy (1,08) (for 2013 Bulgaria was together with France with 1,52).

Bulgaria is for the first time well balanced country for industrial supply and is for 2015-2016 among first 5 countries with return coefficient of 1,05 (on the base of 2011-2014 period) – after Switzerland, France, Hungary, Portugal (3.73, 1.79, 1.39, 1.20) and before Italy (0.94) – the target is 0,90. It gives us some competition advantages.

Dynamics of BG CERN Industrial Supply contracts 2010-2014 (CHF) **Table 1**

years	2010	2011	2012	2013	2014
total volume	455000	547365	751000	1476000	1079228
% vs 2010	100	120	165	324	237
industrial supply return coefficient	0,16	0,34	0,76	1,52	1,18
% vs 2010	100	213	475	950	738

The total volume of executed contracts for second year is above 1 **000 000CHF – 1 079 228CHF.**

PUBLIC RELATIONS

HEAD: ASSOC. PROF. DR MITKO GAIDAROV

The Department “Public Relations” in the Institute for Nuclear Research and Nuclear Energy (INRNE) continue working in 2014 in a close coordination with the colleagues from the corresponding subdivision of the Bulgarian Academy of Sciences (BAS) for a correct and fully transparent repercussions of all events and media appearances of the Institute’s fellows. The traditional meeting of all “PR” departments in the BAS Institutes with representatives of the Governing Body of the Academy helped for this collaboration. At the meeting useful ideas for accelerating the information policy among the Bulgarian community have been shared.

In 2014 Bulgarian Academy of Sciences celebrated 145 years of its foundation. This Anniversary was marked by various activities, in which the Institute took part. One of the main activities was the exhibition “BAS-science for the public and state benefit”. It was opened on 6 June 2014 in the garden in front of the National Theatre “Ivan Vazov” and everybody could able to visit the exhibition till 20 June 2014. The President of BAS Academician Stefan Vodenicharov and Mrs. Jordanka Fandakova-Major of Sofia Municipality opened officially the exhibition, which showed in 30 posters the scientific achievements of the BAS Institutes. INRNE was presented by a poster named “The nuclear science for the progress”, in which different aspects of the Institute’s activities were illustrated: the participation of INRNE in international nuclear centers as CERN (Geneva) and JINR (Dubna), in projects like FOBOS from the Bulgarian Space Program, BEO “Moussala” as an unique ecological observatory in Europe, the scientific assistance of Kozloduy NPP, the activities made for the establishment of the National Cyclotron Center, performing of environmental monitoring, the investigation of artifacts etc. After the exhibition was over in Sofia it traveled to all 14 regional academic centers and, in this way, many people were able to become familiar with a part of the innovative achievements of BAS with important practical applications. Unfortunately, the INRNE poster was not printed in its original form reducing significantly the text and photo material.

On 30 January 2014 a letter to the Minister of Education and Science Prof. Aneliya Klisarova has been sent, which was signed by Prof. Vladimir Dobrev (INRNE-BAS), Prof. Nikolay Tonchev, Assoc. Prof. Oleg Jordanov and others from the Civil Movement for Defense of the Science and Education. In the letter they protested against the lack of changes in the science, law for the academic staff and lack of discussion related with the strategy for academic growth. This letter was partially included in the article of Aneta Petkova entitled “Scientists jumped against the education Minister” in the newspaper “Trud” in its copy of 10 February 2014.

The establishment of a National Cyclotron Center as a future scientific and applied INRNE infrastructure was an object of different discussions. On 18 February 2014 a press-conference, in which several specialists who work on this project took part, was held. The press-conference was broadcasted on “Kanal 3” TV and a short reportage was included in the evening program “Po sveta i u nas” of Bulgarian National TV. On 10 February 2014 TV+ showed a film of the journalist Ivan Takev about the National Cyclotron Center.

On 10 March 2014 Assist. Prof. Hristo Lafchiev discussed with Georgi Kaschiev, expert on nuclear safety in the bTV program “Face to face” on the topic “Nuclear energy safety. Did we learn the lessons from Chernobyl and Fukushima?”.

On 26 March 2014 in an official ceremony in the Coat of Arms Hall of the Presidency Building Academician Ivan Todorov has been awarded with Stara Planina Order First Rank. This high state order was presented to him by the President of Republic of Bulgaria Mr. Rosen Plevneliev in the presence of the Minister of Culture Peter Stoyanovich, the Minister of Education and Science Aneliya Klisarova, as well as the Director of INRNE Assoc. Prof. Dimitar Tonev. Academician Ivan Todorov is one of the most prominent and respected physicists in Bularia and all over the world. He is among the experts who advises the Nobel Committee when nominating candidates for this most prestigious international award. Academician Todorov is a co-author of many remarkable works and he is among the founders of the axiomatic method in the Quantum Field Theory. As a prominent scientists he is one of the founders of the prestigious School on Mathematical Physics in Bulgaria. Academician Todorov has participated in the training of generations own scientists inspiring them by his dedication to the science. Academician Ivan Todorov delivered a speech in the official ceremony thus expressing his own thankfulness to the President Rosen Plevneliev and to all awarded prize-winners, as well. He was grateful also for the attention that the President showed to the spiritual heritage in Bulgaria. In his short speech Academician Todorov said that he accepts the award as a recognition of the Bulgarian science and the role of the BAS for its development. In his final words, Academician Todorov noticed that “The hearths of culture, including also the fundamental science, are not luxury accessed for reach countries only. Their maintenance is not cost dear compared to the long-term effect they are charged with. Bulgaria continues giving talented youths. The latter have to find a society, in which they can advance and to which come back when had possibility to learn something in abroad”.

On 9 April 2014 in the Institute a seminar was held, in which Academician Victor Matveev, Director of JINR, Dubna, Russia, delivered a lecture entitled: „JINR: State of Today and the Perspectives for Tomorrow”. Acad. Matveev has visited Bulgaria to bestow him a diploma for a foreign member of BAS on 10 April 2015. The lecture was attended by the INRNE leadership and many colleagues from the Institute, from the Institute of Solid State Physics, Institute of Electronics, the Chairman of the Nuclear Regulatory Agency, from Sofia University “St. Kliment Ohridsky” and others. After the lecture a meeting of Acad. Matveev with the INRNE leadership was organized. Victor Matveev is a well-recognized all over the world scientist in the field of elementary particles physics, theoretical and mathematical physics. The main directions of his research are related with the development of the Quantum Field Theory in construction of relativistic quark models of hadrons and description of dynamical symmetries in the elementary particles physics at high energies. In the period 1965-1966 together with B.V. Struminsky and A.N. Tahvelidze they obtained original results in the creation of the hadrons quark theory. They introduced a new quark quantum number, which later was called “colour”. This result is a basic one for the progress of the elementary particles physics-the quantum chromodynamics. In another cycle of papers together with R.M. Muradyan and A.N. Tahvelidze, the automodelity principle in the high energy physics has been formulated. This principle gives possibility for a unitary approach for scale-invariant description of deep inelastic processes at high energies and large momentum transfer. The proposed rules of quark calculation in 1988 have been registered as a discovery in the USSR Discoveries Register. Victor Matveev developed the concept of “hidden” colour in nuclei and showed the importance of the quarks degrees of freedom in the nuclear structure at short distances, the so-called relativistic nuclear physics. In 1991 he was elected as a Corresponding Member of the Russian Academy of Sciences (RAS). In 1994 he became an academician of RAS. In the same year he was elected as a member of the Presidium of the RAS and Vise-President of the Physics Section. From 2008 till 2013 Victor Matveev is a President of the Physics Section of the RAS. Since March 2011 he is Director of JINR after he was elected by the Committee of Plenipotentiaries of the Governments of the JINR Member States. Information on the visit of Acad. Matveev in Bulgaria was published in newspapers “Standard” and “Zemya”**,** PowerIndustry-Bulgaria.com (specialized portal for energy), bgnow.eu, actualno.com and others.

For a second consecutive year in the Night of Museums-17 May, the Regional Library “Lyuben Karavelov” in Ruse organized “Night in the Library”. Dr. Boyko Vachev, Head of Bureau CERN in the Institute, presented an exhibition of drawings “From the “God Particle” to the Bulgarian Buildings”.

In the end of May 2014 INRNE performed a patriotic action. Boyko Vachev endowed 309 books in Bulgarian to the youths of Ostrovnoe village (the ancient name is Babata), Odessa Region, Ukraine. In this village with 1 000 people compact Bulgarian population about 200 years ago Bulgarian gardeners settled there. The idea of the youths who are members of the Bulgarian Youth Club “Active” is to create a library with Bulgarian books.

On 25 and 26 June 2014 the first working meeting on two INRNE projects as a part of the collaboration between BAS and Macedonian Academy of Sciences and Art (MASA) was held. In the meeting took part experts from Bulgaria and Macedonia, as well as from BAS and MASA and other organizations. The aim of this first working meeting was to present the electric power system in Bulgaria, nuclear energetics in Bulgaria and perspectives of its development, as well as the electric power system in Macedonia. Assoc. Prof. Dimitar Tonev-Director of INRNE and Assoc. Prof. Pavlin Grudev had presentations in the meeting. Other participants from the Institute were Assist. Prof. Neli Zaharieva, Assist. Prof. Antoaneta Stefanova and Assist. Rositsa Gencheva.

From 27 July till 2 August 2014 in CERN (Geneva) the Sixth National Teachers Program for training of teachers on physics and astronomy took place. 35 teachers and four experts on natural sciences had a chance to be in specialized laboratory of CERN. The main goal of the program is the Bulgarian teachers, participants in the training, to develop packets of activities for application of the received knowledge in the school training on physics, astronomy and other natural sciences. In addition, from 5 till 10 October 2014 another Teachers Program was held, which included lectures by INRNE scientists (Assoc. Prof. Plamen Yaidjiev, Dr. Petar Vankov), scientists from other BAS Institutes, Sofia University “St. Kliment Ohridsky” and Bulgarians who work in CERN. Coordinator of the Teachers Program is Prof. Vladimir Genchev. In contrast to previous years when the Teachers Programs were concentrated on physics, the second program for 2014 was focused on different aspects of engineering developed in CERN. Lectures on electronics, electro-engineering and mechanics were red. The teachers visited several experimental facilities on the CERN territory, which allowed them to become familiar in details with the scientific research carried out in this European scientific center. An information about the conducted Teachers Programs and responses from the training can be found in posredniknews.com from 6 August 2014, oshtepan.com from 9 July 2014, gpche-smolyan.com, montana-dnes.com from 27 October2014, varnautre.bg from 19 November 2014 etc.

On 29 July 2014 a Memorandum of Understanding (MoU) for collaboration between INRNE-BAS and Pennsylvania State University, USA, has been signed. The ceremony took place in the Institute. Before it Prof. Kostadin Ivanov from this University gave a lecture entitled: "AP1000 Activities at PSU in Cooperation with Westinghouse Related to Undergraduate and Graduate Education, Training and Research". Colleagues from the Institute and officials from the USA Embassy in Sofia attended the seminar, as well as people from Nuclear Regulatory Agency, Kozloduy NPP, Sofia University "St. Kliment Ohridsky", Technical University-Sofia, ENPRO Consult OOD, Risk Engineering AD and others. In 2014 another MoU for collaboration was signed between INRNE-BAS and Nuclear Power Institute Texas A&M University/Texas Engineering Experiment Station, USA. The ceremony took place in Bucharest, Romania, during an international conference.

On 12 and 13 September 2014 in Flamingo Grand Hotel in Albena Resort a Workshop for Stakeholders Information and Consultation on EMERSYS project was held. The Workshop was organized by the INRNE-BAS as a Partner 4 in the EMERSYS project "Toward an integrated, joint cross-border detection system and harmonized rapid responses procedures to chemical, biological, radiological and nuclear emergencies" MIS-ETC Code 774. The project is under Romania-Bulgaria Cross Border Cooperation Programme 2007-2013 and is co-financed by the European Union through the European Regional Development Fund. The project is of great importance for the Bulgarian national security. The Workshop aimed to provide the local authorities (majors and governors) with information on the project and to give directions for future coordination between the Bulgarian regional governmental offices from Romania-Bulgaria cross-border area. The Governor of the Regional Administration-Ruse Simeon Ivanov, the Major of Tsenovo Municipality Dr. Petar Petrov, experts of different levels from the Regional Administrations in Ruse, Pleven, Silistra, Vratsa and from the Municipalities of Dobrich, Ruse, Silistra and Oryahovo took place in the Workshop. From Romanian side participated Dr. Mitică Drăguşin from the Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH), which is a Lead Partner in the EMERSYS project, and two representatives from the General Inspectorate of Emergency Situations (GIES) in Romania- Lt. Col. Francisc Senzaconi (Project Responsible for Partner 2) and Lt. Col. Engineer Benone Gabriel Duduc (Chief of the Department for Prevention of Disasters at GIES). On behalf of the other Bulgarian Partner, Fire Safety and Civil Protection Chief Directorate, Ministry of Interior, took part Lyudmila Simeonova, Head of CBRN Department and Project Responsible for Partner 3, and Lyudmila Stratieva, expert in the Department of International Projects. After the official opening of the Workshop with moderator Assoc. Prof. Mitko Gaidarov, Assoc. Prof. Dimitar Tonev-Director of INRNE reported on the main research which is performing in the Institute and outlined the new projections of its activity in the next few years. Assoc. Prof. Maria Manolova, Project Responsible for Partner 4 and Vise-Director of INRNE-BAS presented the main activities that are carried out by the Institute within the project for the period of its beginning July 2013 till now. The technical equipment of the CBRN (Chemical, Biological, Radiological and Nuclear) Mobile Unit, which has been received by INRNE under the project and includes installations for detection, localization and identification of harmful CBRN agents in case of emergency, as well as for decontamination of the staff and population and the possibilities of different uses, were the subject of the presentation of Dr. Galina Asova from INRNE. In the last report for the first day of the Workshop given by Lyudmila Simeonova, she made the participants familiar with the activities, which the Fire Safety and Civil Protection Chief Directorate, Ministry of Interior, implements, namely: 1) building of technical possibilities to find, evaluate and prognosticate CBRN contamination; 2) harmonization of national plans and procedures to response to accidents raised by CBRN agents and materials; 3) development of common platform of bilateral exchange of data between national operational centers in Bulgaria and Romania in case of accidents. The second day of the Workshop started with the lecture of Dr. Mitică Drăguşin, in which he gave the overall technical and financial characteristic of the EMERSYS project and informed the audience that a similar Workshop for Stakeholders Information and Consultation for the Romanian local authorities will be held soon. At the same time he noticed that the first training courses will start in November-December 2014. The Workshop finished with discussion, in which different aspects concerning the EMERGY project of common interest were touched. An article on this Workshop has been published in the NEWS Monthly Informational Bulletin of BAS about Science and Technologies, No. 8 (2014). In the summer of 2014 the Institute received a CBRN Mobile Unit which is equipped with the high level modern installation for detection, localization and identification of harmful CBRN agents in case of emergency, as well as for decontamination of the staff and population.

In 2014 CERN celebrated 60 years of its foundation. In this powerful scientific center a number of scientists from the Institute has contribution. On 6 October 2014 on this occasion Kanal 1 of BNT in its program “V kadar” showed a movie of the journalist Maria Cherneva “Hunters of dark matter”. This anniversary and other topics related with present and future activities of the Institute, were the subject of the interview of Assoc. Prof. Dimitar Tonev in “Nicky Kanchev Show” on Darik Radio on 3 July 2014.

From 24 till 28 November 2014 an Annual Meeting of MAGIC (Major Atmosphere Gamma-Ray Imaging Cherenkov) experiment took place in Sofia, in which more than 100 scientists participated. This event was organized by group of colleagues from INRNE together with Italian Cultural Center in Sofia. MAGIC is one of the largest astrophysical experiments in the world and is located in Spain on 2 200 m altitude. About 170 scientists from 10 countries take part: Bulgaria, Germany, Spain, Italy, India, Poland, Croatia, Finland, Switzerland and Japan.

An article entitled “Vision of one Bulgarian scientist in CERN for the future technologies” was published in two electronic media www.infobulgaria.info and www.dariknews.bg from 11 December 2014. In this material the 31-years old PhD student Mircho Rodozov from INRNE tells about advanced-guard technologies that are expected-cars, which use electric engine, quantum computers, which are supposed to increase significantly the power of calculations, development of effective thermonuclear reactor, which will ensure the increasing energy needs and operating with almost free fuel. The young Bulgarian scientists believes in these future technologies, which will "shoot" us ahead as community and civilization and reminds that almost all situations that make our life easier are due to implementation of new technologies. The 31-years Mircho Rodozov together with a group of colleagues from BAS and Sofia University "Sv. Kl. Ohridsky" take part in the CMS (Compact Muon Solenoid) experiment on the Large Hadron Collider in CERN. The experimental program continues and is expected that the accelerator will operate in the Spring 2015 at higher energies. "We hope to observe these new particles because the energy will increase twice", said Mircho Rodozov.

On 3 and 4 December 2014 in Rila Hotel in Sofia a training course on theoretical aspects of chemical and biological emergencies was carried out. This training was organized by the INRNE-BAS as a Partner 4 in the EMERSYS project. On 5 and 6 December 2014 another course on theoretical aspects of radiation protection in radiological emergencies was carried out. Totally there were 38 trainees, from which 22 from Bulgaria and 16 from Romania. They represented the regional services and subdivisions of the Chief Directorate Fire Safety and Civil Protection within the Bulgarian Ministry of Interior, the General Inspectorate of Emergency Situations in Romania and INRNE as partners in the EMERSYS project.

On 8 December 2014 in an official ceremony the President of BAS Academician Stefan Vodenicharov presented with an Award of Distinction and Diploma the President of the National Institute for Nuclear Physics (INFN) in Italy Professor Fernando Feroni. The ceremony was attended also by members of BAS Governing Bodies and the INRNE leadership. In a friendly discussion Prof. Feroni informed the presents about projects that are carried out in the INFN structures and the possibilities of signing contracts for collaboration between INFN and BAS. It will be very important for the training and specialization of young people from both organizations, as well as to implement joint investigations in the field of the experimental and theoretical physics. Acad. Vodenicharov shared with the guest the readiness to extend the scientific contacts between INFN and BAS. Nowadays Fernando Feroni is a Professor in Sapienza Universita' di Roma in Rome. His scientific career has passed also in the University of Ancona (Italy), CERN (Switzerland) and SLAC (USA). He has reach scientific activity-participation in number of experiments in CERN, SLAC and National Laboratory Gran Sasso (Italy). Prof. Feroni is a member of many scientific councils and organizing committees of famous international forums (conferences and schools). Before awarding, Prof. Feroni gave a lecture in INRNE, which was dedicated to the biggest institution in Italy in the field of nuclear physics research. He mentioned that INFN represents a community of researchers who want to discover the secrets of the Universe and to contribute to the innovative technologies for the public benefit. Assoc. Prof. Dimitar Tonev-Director of INRNE informed the audience about signing of contract for collaboration between INFN and INRNE as basic institutions in Italy and Bulgaria in the field of the nuclear physics and its applications at low and high energies.

On 17 December 2014 the 50th Anniversary from the beginning of exploitation of the first in Bulgaria repository for radioactive waste was celebrated. Since its commissioning in 1964, until 2006, the Permanent Repository for Radioactive Waste-Novi Han was managed by the INRNE in accordance with the country's legislation and with the recommendations of the International Atomic Energy Agency, Vienna. The repository was designed for storage of radioactive waste resulting from the application of radioactive sources in medicine-for diagnostics and treatment, as well as in industry, science and education. The celebration collected many guests, among them representatives of Ministry of Energy, Nuclear Regulatory Agency, National Center of Radiobiology and Radiation Protection, BAS, INRNE, Institute of Metal Science, Equipment and Technologies “Acad. A. Balevski” with Hydroaerodynamics Centre, Sofia University “Sv. Kl. Ohridsky”. Assoc. Prof. Dimitar Tonev-Director of INRNE delivered an address. Different media published materials about this event, including electronic ones atominfo.bg (The Bulgarian nuclear site) and kozloduy-bg.info from 19 December 2014.

TRAINING CENTER FOR SPECIALIZING EDUCATION IN INRNE

HEAD: ASSIST. PROF. ARI ARTINIAN

The Training Center for Specialized Education (TCSE) at INRNE opened doors five years ago. TCSE is an independent unit under the direct control of the Institute’s Director. The Center has been founded according to the Nuclear Regulatory Agency Ordinance’s terms and conditions for acquiring professional qualifications and procedures for issuing licenses for specialized training. INRNE has a license for this activity for a period of 5 years starting from 16.12.2009 – Seri’s № CO Reg. № 03164. At the end of 2014 (16.12.2014) TCSE received an extension of the license for specialized education under the number Seri’s № CO Reg. № 04692 .The main goal of the center is to pursue studies on the basis of specialized training programs and development of courses and procedures for specialists, qualified for activities in the field of ionizing radiation.

There are several experts working at the center taking care of the academic activities, quality assurance, the organization of the processes of training and technical support. INRNE’s website provides information for the educational center, curriculums, proficiency levels, how to register for courses, etc.

The training center has a separate modern training room equipped with the necessary audio-visual equipment for presentations. A team of 8 highly qualified professors and associate researchers - INRNE official’s lecturers had been teaching on separate programs for different levels of training. In addition, demonstrators expand the practical knowledge of the students on the different subjects in the special laboratories and facilities of the Institute. The course aims at the acquainting students with nuclear physics theory, the principles of radiation protection and safe use of sources of ionizing radiation (SIR) as well as the current legislation in this area. As a result of acquired knowledge and experience, the goal is to build prerequisites for obtaining a radiological culture.

The TCSE team prepares initial and periodical training for four qualification levels. The levels are grouped according to the activities, included in the job descriptions of the students and their functions related to radiation safety. The students are specialists with secondary and higher education, working with or using open and sealed sources of ionizing radiation, and generators of such radiation. These are mainly scientists and specialists from the Institutes of BAS and universities, heads of companies and establishments, service workers, controlling and measuring X-ray equipment, and working with radioisotope technology in companies in the fields of mining, energy, and medicine.

Licenses for the use of nuclear energy are issued to all students who successfully complete the courses and the exams before the Qualification Examination Board in INRNE. TCSE prepares and conducts removed training for professionals at their working places. This is done primarily for groups over 10 people with the same licenses who participate in continuous manufacturing or process control. These courses are mainly for the staff performing nondestructive tests in large companies for repairing and building ships and power stations. Another large group of students are those of the specialized control of luggage, vehicles and trafficking by guards, border police, customs officials, and others.

For the past 5 years 78 specialized courses for initial training, including all levels of qualification and 14 courses for supporting training were held at the TCSE. More than 1000 students from more 40 organizations and companies were trained.

The TCSE at INRNE remains the only center covering such wide range of professions. We will continue our efforts to improve the teaching process, to satisfy the needs of qualified and useful training in order to ensure the safe use of nuclear methods

LIBRARY

HEAD: TANYA MARKOVA

In the past 2014 some growth of the main indicators in the library activity can be seen. On first place we must point out that all our readers had the opportunity to use e-subscription of all series of one of the main physical journals – Physical review. They also had access to other e-data bases like Scopus, EBSCO, Science Direct, SpringerLink.

During 2014 306 volumes of literature were provided. From them, traditionally, the biggest part is from book exchange – 206 volumes, followed by the provided by subscription or purchase – 78 volumes and the received as gift – 22 volumes.

The used library materials are 5473 volumes. From them 2684 volumes are in reading room, 2753 volumes taken for home from readers and 36 volumes sent in other libraries. 494 readers were registered – 370 from the scientific unit, 58 from BAS system, 29 from Sofia University and 37 from other institutes in the country.

The work on electronic cataloging of books from the library fund continued. 1775 volumes of literature were described and put in the e-catalog. During past 2014 our library received big donation from Siemens. All journals were reviewed and described. Part of them is ready for processing and will be added to the library fund.