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I. Main duties of the research unit in 2013

The main tasks of the research institute, according to the deed of foundation, are the following: fundamental and applied research in nuclear-, atomic-, and in particle physics. The researchers of the institute apply physical knowledge and methods in other fields of science (material sciences, earth science and environmental research, medical-biological research) and also in practice. They develop equipment and methods for fundamental and applied science. The institute performs supplemental activities in the area of its fundamental activity.

II. Outstanding research and other results in 2013

a) Outstanding research and other results

Quantum Physics

Dimensonality of quantum states is an important resource in quantum information theory (we may think of quantum cryptography protocols or fault tolerant quantum gates based on implementation of systems in higher dimensional systems). Dimension witnesses allow one to test the dimension of an unknown physical system in a device-independent manner, that is, without placing assumptions about the functioning of the devices used in the experiment. In our work we presented dimension witnesses for quantum systems of arbitrary Hilbert space dimension. Our approach is deeply connected to the problem of quantum state discrimination, hence establishing a strong link between two research topics that have recently attracted attention.

In the surface integral formalism of the scattering theory the Coulomb modified plane wave plays a substantial role. This function appears in the asymptotic form of the wave function and also enters into the expression of the cross section. The partial wave expansion of this function was carried out and the asymptotic form of it was studied. Four equivalent forms were found which can be used for the accurate and quick determination of the function. The known asymptotic form was improved thanks to the four equivalent forms. The accurate knowledge of the asymptotic form may lead to a simplified asymptotic form for the scattering of charged particles.

A new composite symmetry of the nuclear structure, called multichannel dynamical symmetry (MUSY) is established. It connects different clusterizations of the same nucleus, like e.g. the ^{24}Mg+^{4}He and ^{16}O+^{12}C configurations in the ^{28}Si. (The channel refers to the reaction channel that determines the cluster configuration.) There are experimental evidences for the coexistence of different clusterizations in several nuclei, and this new symmetry can describe them in a unified framework. Therefore, it has a considerable predictive power; e.g. the energy-spectrum of one clusterization may completely determine the other spectrum. This work exploits the exact mathematical background and detailed physical content of the MUSY.

The alpha-cluster states of ^{22}Ne were studied within the framework of the semimicroscopic algebraic cluster model (SACM). The band structure, energy spectrum as well as E2 and E1

transitions were calculated and were compared with the experimental data. The results were also compared with those obtained from two microscopic models (DAMD and GCM). It was found that the prominent bands obtained in the latter frameworks all have equivalents in the SACM and the agreement between the calculated spectroscopic properties is rather good, especially for positive-parity states. Further bands were also predicted, but the experimental data set is not rich enough for a firm band assignment.

Particle Physics

The 2013-2014 Long Shutdown of the LHC gives excellent opportunity to the Atomki group to summarize the experiences gained by the alignment system and allows them to perform its necessary maintenance and its upgrade. The purpose of the upgrade is three-fold: further improvement of the accuracy, reacting possibility for a further study of the twist-effect and also some of the hardware modifications that allows the maintenance of various parts without waiting for the opening of the CMS wheels. In practice this means that on the top of the already operational 600 we install further 40 camera sensors on the so called MiniMAB structures. The 36 rigid structures (known as MABs) playing a key role in the alignment system are now equipped with better performing targets that can be observed by the survey technics even when the CMS detector is closed. This modification allows them to better understand the above mentioned twist effect. Furthermore, those mini computers that are responsible for the readout and digitalization of the camera images are now being moved to the periphery of the detector therefore improving their accessibility during the closed configuration.

A new type of regulator of functional renormalization group method has been proposed in 2012 (published in 2013) which recovers all major types of regulators in appropriate limits. The numerical optimization its functional form, i.e. the optimal choice of its parameters has been determined by two different methods. On the one hand, the optimization is performed in the framework of the three-dimensional O(N=1) scalar field theory by comparing the critical exponents obtained by the new regulator to the best known values (determined by experiments). On the other hand, the requirement for the absence of spontaneous symmetry breaking in d=1 dimension has been used to optimize the regulator-dependence of functional renormalization group equations in the framework of the sine-Gordon scalar field theory.

The spectral statistics of the QCD Dirac spectrum around the mobility edge was studied. It was found that it is described by the deformed random matrix ensemble that is used to describe the critical statistics in the corresponding Anderson model. Using finite size scaling it was shown that the transition at the mobility edge in QCD is a genuine phase transition and its correlation length critical exponent agreed with that of the Anderson model. These results were presented in two parallel and one invited plenary talk at the 31st International Symposium on Lattice Field Theory in Mainz, Germany.

Nuclear Physics

The $^{3}He(\alpha,\gamma)^{7}Be$ reaction plays a key role both in the hydrogen burning process in the Sun and in the big-bang nucleosynthesis. There is a strong contradiction between the two available experimental datasets in the weakly studied high energy range of this reaction. This contradiction influences strongly the extrapolation to low energies and increases the uncertainties of astrophysical models. In order to address this problem, a new measurement has been carried out at the cyclotron accelerator of Atomki with the activation method in the problematic energy range. The new results contribute to the increased accuracy of astrophysical models.

The study of low energy alpha-induced nuclear reactions revealed that the available alpha-nucleus optical potentials are not able to describe well the experimental data at astrophysical energies. This increases substantially the uncertainties of e.g. the astrophysical gamma-process models. Based on the systematic study of elastic alpha scattering experiments carried out at Atomki, a new alpha-nucleus optical potential has been developed specifically for astrophysical purposes. This so-called Atomki-V1 potential will be developed further in the future by the inclusion of more experimental data.

In GSI within the RISING collaboration the quadrupole collectivity of ^{104}Sn has been measured by use of Coulomb excitation in order to clarify the anomaly observed in the B(E2) values of light Sn isotopes. It has been shown that ^{104}Sn - contrary to its heavier neighbours - follows the trend expected from shell model, although due to the relatively large uncertainty, some room is left for enhancement of collectivity.

The strength of the effective proton-neutron interaction has been studied in the weakly bound ^{26}F by a GANIL collaboration using isomer spectroscopy. It has been shown that the strength of the effective interaction is weaker than in the nuclei close to the stability line. This effect has been assigned to the three body forces in coupled cluster calculations.

A new time of flight neutron spectrometer (European Low Energy Neutron Spectrometer, ELENS) has been built in Atomki in a wide international collaboration by using EU support for studying spin-isospin giant resonances in radioactive beams by (p,n) reaction. The spectrometer consists of specially wrapped fast plastic scintillator bars with dimensions of $10\times45\times1000$ mm^3. One of their unique feature is their high angular resolution (<1 deg.). After measuring the characteristics of the spectrometer, it was already used successfully in a nuclear physics experiment as well.

A new method has been suggested for measuring the neutron-skin thickness. It is based on the excitation of the anti-analog giant dipole resonance (AGDR) in (p,n) reaction. The energy of the AGDR depends very sensitively on the neutron-skin thickness, so by measuring the energy of the AGDR, the thickness of the neutron skin can be deduced. The successful test of the AGDR method paved the way for their usage in neutron-rich radioactive nuclear beams. Determining the thickness of the neutron skin is important for constraining the symmetry energy part of the nuclear equation of state, which is essential for modelling and understanding the neutron stars and many other phenomena in nuclear astrophysics.

The photofission cross section of ^{238}U was measured at sub-barrier energies as a function of the γ-ray energy using a monochromatic, high-brilliance, Compton-backscattered γ-ray beam. The experiment was performed at the High Intensity γ-ray Source (HIγS) facility of Duke University at beam energies between $E\gamma$=4.7 MeV and 6.0 MeV and with ~3% energy resolution. Indications of transmission resonances have been observed at γ-ray beam energies of $E\gamma$=5.1 MeV and 5.6 MeV with moderate amplitudes. The triple-humped fission barrier parameters of ^{238}U have been determined by fitting EMPIRE-3.1 nuclear reaction code calculations to the experimental photofission cross section. In the future similar experiments are planned also at ELI-NP in Bucharest.

High-spin states of ^{91}Ru have been studied from ^{58}Ni(^{36}Ar,2pnγ) fusion-evaporation reaction at a beam energy of 111 MeV using the EXOGAM Ge clover array. Measurements of linear polarization and angular distribution of the γ-rays have led to firm assignments of spins and parities of the high-spin states. Calculations using a semiempirical shell modell were performed and the theoretical results were compared with the experimental level scheme to understand the structure of the first and second ($17/2^+$) and ($21/2^+$) states. The good agreement between the theoretical and experimental data supports the interpretation of the second ($17/2^+$)

and $(21/2^+)$ states as members of the seniority-three $\nu(g_{9/2})^{-3}$ multiplet.

The detailed spectroscopy of ^{150}Sm and ^{152}Gd has been studied using (α,xn) reactions and the γ-ray arrays AFRODITE and JUROGAM II in order to investigate the structure of the 0_1^+ ground state and the first excited 0_2^+ state. This information is required to understand the branching of double β decay to these states from ^{150}Nd. Additional intra-band $E1$ transitions between the 0_2^+ bands and octupole bands in both ^{150}Sm and ^{152}Gd have been observed. The relative strengths of the $E1$ transitions and the behaviour of both 0_2^+ bands argues for, but does not prove, the interpretation of the ground state being quadrupole deformed whereas the 0_2^+ state has an additional octupole deformation.

Applied Nuclear Physics

In 2013 four measurement campaigns were carried out within the CHARISMA EU FP7 project; altogether 9 foreign researchers were received from the Czech Republic, France and Poland. Distribution of elements in ancient otholits as well as dripstones, trace elements in samples taken from the walls of caves and the elemental composition of jewellery from the early Iron Age were determined. In addition, the evaluation, interpretation and publication of formerly obtained measurement data, with the help of Bulgarian and Romanian colleagues, were accomplished. For two research topics (antique ceramics from Greece, metal objects from the Carpathian Basin) the work started within the framework of CHARISMA was continued.

In this work, the chemical changes in poly(dimethylsiloxane) (PDMS) induced by proton irradiation of various energy and fluence was investigated. It has been found that the forming products vary as the energy of the proton changes, which means that the energy of the incident ions can influence the chemical mechanism. This is caused by the variations in the ion-molecule interactions, i.e. the change of probability of ionization and excitation of the molecules. Reaction mechanisms for the processes taking place in PDMS by different energy proton irradiation was proposed. This unique effect may be used for various purposes, such as to create advanced materials with buried ion-induced modifications or to understand better the heavy ion irradiation induced reactions which have crucial importance for example in proton therapy.

The MiniPET-2 scanner was applied in catalytic experiments. The camera was developed in the Atomki in collaboration with the University of Debrecen for small animal preclinical imaging. The camera has 12 detector modules in a full ring configuration. The 3D image was formed from 35 cross-sectional slices. The PET has been used to image the 3D location and quantitative distribution of ^{11}C-methanol compound in zeolite type catalyst bed (the catalyst bed was 4 cm in length and 1.6 cm in diameter). The small-animal PET scanners have great potential for imaging of well-functioning, poorly functioning, or partially covered catalyst surfaces in academic and industrial research for the development of catalysts. The technique gives quantitatively correct characterization for both axial and radial imaging of the catalyst bed because the distribution of radioactive compounds is analyzable in the total catalyst volume.

In the frame of the project Central Nervous System Imaging, researchers of Atomki developed the MiniPET-3 small animal PET scanner in collaboration with the University of Debrecen and international partners. In the detectors forming a ring, the traditional photomultipliers are replaced with silicon based photomultipliers. The latter is insensitive to the magnetic field so enables the fusion of PET and MRI imagers. The other great result of this project is the BrainMOD software which can combine and visualize data coming from various medical diagnostic equipments (PET, SPECT, MRI, EEG, EIT).

Preparation of several micrometer thick gadolinium layer was made for excitation function measurements for the production of medically important terbium isotopes. The research has no antecedent, since so far only several nanometer thick layer could have been prepared for industrial purposes. Electrolysis from Gd containing solutions at room temperature was applied, since the high temperature electrolysis from melts, used for industrial purpose, can not be used. Aluminium was used as a least disturbing support in the measurement of the spectra after irradiation.

The researchers of Atomki played a crucial role in the CRP project launched by the International Atomic Energy Agency on "Accelerator-based Alternatives to Non-HEU production of Mo-99/Tc-99m". They modeled the cyclotron production of ^{99m}Tc and studied the yield of ^{99m}Tc and the amount of Ru, Tc, Mo, Nb and Zr impurities as a function of the proton energy, irradiation, cooling time and target isotope composition. Optimization calculations on production parameters of ^{99m}Tc were performed. They estimated the expected change in the isotopic composition and elemental impurities of the 99.5 % highly enriched ^{100}Mo after repetitive high intensity irradiations. The research group contributed to the results of the CRP project "Improvements in Charged-particle Monitor Reactions and Nuclear Data for Medical Isotope Production" by new measurements and extended compilation. Widely used CRP data libraries have been updated.

New type scintillation neutron detectors were studied. Different liquid and solid scintillators were combined with photomultiplier tubes and SiPMs for neutron detection. The tests were done in the Cyclotron Laboratory of MTA Atomki with quasi-monoenergetic d+D neutrons. The neutron-gamma discrimination was done using a digital signal processing unit. Developments of new algorithms for selecting the neutron induced signals have been started. Similarly, development of the algorithm needed for unfolding the neutron spectrum has been started. The aim of the project is the development of new types of scintillator – photomultiplier combinations for neutron detection in nuclear physics experiments (e.g. study of delayed neutron emission).

The researchers of Atomki participated in the development of a new method for measuring fluxes of ions escaping fusion plasmas. The experiments were performed at the ASDEX Upgrade tokamak (IPP Garching, Germany). The detectors were irradiated in the middle plane of the tokamak. The experiments modelled the cases of D-D discharges in the future International Thermonuclear Experimental Reactor (ITER). Simulation of the experiment was done by the ASCOT code. Results of the simulations were compared with measured ion fluxes. Improvement of the method and optimization of future experiments have become feasible.

New irradiation devices were developed and manufactured for the most frequently used types of samples, which were also tested and used in real conditions. The goals of these developments were the more accurate beam current measurement; to minimize beam time and the radiation load for the personal. The use of less frequently applied radioisotopes (e.g. ^{65}Zn) was optimized, and a new method based on the activation of the minor components of the sample was developed according to the needs of their cooperation partners. The methods were optimized for application of activities under the free-handling limits, which made possible a simplified transport, storage and work in partner institutions with limited licence for handling radioactive material.

Atomic collision processes

Formation of negative hydrogen ions with high velocity was observed in molecular collisions. The present observations indicate that H^- ions are created from every H-containing molecule in a general collision process, which does not require special initial state of the molecule. Earlier it was assumed that, from molecular species, H^- ions can be emitted only if, by electron capture or excitation, an excited state is formed, which dissociates spontaneously. The presently observed H^- ions originate from two body collisions involving large energy and momentum transfers. Since the hydrogen anion plays an important role in astrophysical and laboratory plasmas and is an active participant of many chemical reactions, this new process may turn out to be significant in many fields.

An analysis of the charge transfer mechanism in the collision of multiply charged ions with molecular and biomolecular targets is performed, considering the non-adiabatic interactions between the molecular states involved. Collisions of doubly charged C^{2+} ions on small molecular targets, *CO* and *OH*, have been investigated, together with the analysis of charge transfer between C^{4+} ions on uracil and halouracil biomolecular targets. The process is studied theoretically by means of *ab initio* molecular calculations followed by a semi-classical treatment of the collision dynamics. The influence of rotational couplings is discussed with regard to the collision energy. Strong anisotropic and vibration effects are pointed out. The study provides an order of magnitude estimate of the radiosensivity properties of halouracil molecules which may be of medical interest.

In an international collaboration in Japan (National Institute for Radiological Sciences, Chiba, Japan and Toyo University, Tokyo, Japan), iron plasma and iron ion beam was produced by an ECR ion source. The design of the source was made by the active participation of the researchers of Atomki in the previous years. The extracted and decelerated iron ions were implanted into an evaporated fullerene (C_{60}) layer in order to produce a new molecule of $Fe+C_{60}$. This treated material was examined by physical and chemical methods (MA-LDI, HPLC). It was shown that molecules with mass number of M=776 were created and their size did not exceed the size of C_{60} molecule having a mass number of 720. This way an indirect proof was given that atomic iron encapsulated in fullerene cage was created (the mass number of iron is 56). These results were published in two international journals. Further research is necessary to make this method reproducible and for producing the material in bulk quantity.

Two week beam times were used at the P04 beam line of PETRA III synchrotron (DESY, Hamburg, Germany). The excitation/ionization cross sections of Xeq+ (q=1- 3) ions were investigated in the photon energy range of the 3d resonant excitations with a special photon-ion spectrometer (PIPE). Similar measurement was performed for the 1s excitation of the carbon atoms in the endohedral clusters (Lu@C80).

Ion guiding through nanocapillaries in polyethylene terephthalate (PET) were studied in an international collaboration at KVI Groningen, The Netherlands. These experiments were initiated in view of a previous study with capillaries in polycarbonate for which strong blocking effects were observed, whereas for PET these effects could not be detected. The aim was to find out whether the different results are caused by differences in the materials or by differences in the areal densities of the capillaries. The experiments were performed for a variety of PET samples with different areal capillary density. The tilt angles were close to zero degree because previous blocking effects were found to be largest at small angles. Our results clearly show that blocking effects also exist for PET if the areal capillary density is high enough. To explain the results, the potential produced by the charges accumulated in neighboring capillaries was calculated showing that it plays an important role in the ion blocking.

Applications in Atomic Physics, Solid State Physics, Surface Sciences

Double-differential spectra of coincidences between backscattered electrons and secondary electrons (SEs) emitted from polycrystalline Al excited by primary electrons of 100 eV energy, were measured. In the coincidence data events can be distinguished due to the process when the primary electron suffers a surface energy loss in vacuum near the surface, exciting a SE from the uppermost surface layer. At energy losses of the primary electron, just above the bulk plasmon energy, a sharp transition is observed that corresponds to the sudden increase of the depth of SE ejection, as a direct consequence of the complementarity of surface and bulk plasmons (Begrenzung). The processes observed are of general relevance for SE emission near surfaces and therefore for SE microscopy.

The angular and energy dependence of surface and bulk plasmon energy losses of photoelectrons were modeled for deep core excitations in simple metals Al and Na. Multiple scatterings of photoelectrons were fully considered using the quantum Landau formula. Assuming only single elastic scatterings overestimates the losses from deep emitters due to forward focusing effects, yielding poor results for the depth profiles and the loss spectra. The model accounting fully for multiple scatterings gives a rapidly decaying depth profile due to defocusing effects and rich structures due to photoelectron diffraction, furthermore, successfully explains the azimuthal dependence of the loss spectra, influenced by the local geometry around the emitters.

An Atomic Layer Deposition apparatus was installed in the frame of the Materials Research Laboratory. Transparent conductive oxide layers (boron doped ZnO) prepared by chemical vapor deposition and thin magnetic films (FeNi alloys) prepared by electrochemical deposition were studied by depth profile analyses. A unique method, the inverse depth-profile method, was developed to reveal the near substrate depth composition of constituents of thin magnetic films produced by electrodeposition, and so basic processes of deposition could be studied. The duty cycle and current density were determined for the production of galvanostatic pulse-plated FeNi alloys.

Low temperature investigations of induced optical properties of $As_{20}Se_{80}$ chalcogenide samples were carried on, namely, the effects of a laser beam induced atomic motion (mass transport) in chalcogenide thin films were studied. Since the sample temperature is extremely low, thermal excitation and diffusion as driving force of the mass transport are completely excluded, so irradiation with a laser beam induced structure changes quantummechanically. While the bulk properties were studied optically, the surface atomic motion was studied by low energy ion scattering. Due to the lack of low temperature measurements (at liquid helium or near liquid helium temperatures) in the field of mass transport, the new results in this field are very important.

In the frame of an international cooperation, by combining the mass spectrometry (SNMS) and X-ray diffraction methods it was shown that the growth of the Cu_3Si crystalline layer between the amorphous Si and nanocrystalline Cu thin films follows a linear law. The results play an important role in microelectronics for predicting or increasing the lifetime of the electrical contacts. It is also illustrated by atom probe tomography (APT) that the Si atoms diffuse rapidly on the grain boundaries of the nanocrystalline Cu, leading to Si segregation at the surface and to an increase in the overall Si content inside the Cu layer.

Environmental Physics

It has been shown that formal K – Ar age of clay minerals from soils is youngering when treated with (artificial) fertilizers. This results in the decrease of trace element content of the clays and the foods produced on it. A new method for soil diagnostics might be based on this effect. This undesirable effect of soil deterioration might be slowed by addition of Mg-bearing rocks, e. g. dolomite.

As revealed by 15 AMS radiocarbon and 21 OSL-IRSL ages the Dunaszekcső loess-paleosol sequence is an excellent terrestrial record of paleoenvironmental change in the Carpathian Basin for the last 130 ka. Charcoals from the sequence made it possible to test the accuracy of ^{14}C ages from mollusk shells. This approach revealed that ^{14}C ages from some gastropods having small shells (< 10 mm) are statistically indistinguishable from the ages of plant macrofossils, while others show age anomalies up to 600-800 years. OSL, post-IR OSL and pIRIR@290 ages are found to be consistently older than the ^{14}C ages, except for pIRIR@225 ages that match quite well the radiocarbon ages.

Tritium is produced in the upper troposphere and lower stratosphere in nuclear reactions between atmospheric nuclei and secondary neutrons derived due to cosmic rays. In our region the natural tritium level in the precipitation is around 5−10 TU. Since the 50's the atmospheric thermonuclear bomb tests increased the tritium amount of precipitation by 2-3 orders of magnitude. The tritium in precipitation has already diminished to a stable level, and in the 2000's years it is close to a natural level (~10 TU). In the period of 2001−2012 water samples were continuously taken from each precipitation events. The results show that the tritium concentration of monthly precipitations depends on the magnetic activity of the Sun. This is in accordance with the time series of other cosmogenic isotopes like ^{7}Be, ^{10}Be.

Cellulose is a constituent of the plants that is not reutilised by the metabolism, just generated once, therefore, the changes in the atmospheric ^{14}C activity concentration possibly can be reconstructed by the measurements of the radiocarbon activity in the tree rings. Tree ring series were collected representing the past 17 years (AD 1995-2012) from the vicinity of the Püspökszilágy Radioactive Waste Treatment and Disposal facility and from a distant background area. After the preparation of the cellulose content of the samples the ^{14}C concentration of cellulose was measured by high-precision ^{14}C AMS method. Knowing the results the excess ^{14}C emission of the disposal facility and its temporal changes were determined for the investigated period with a resolution of one year. These data are significantly higher than the natural background. However, the excess is approximately equal to the level of tree rings from the time of the nuclear weapon tests.

Inductively coupled plasma mass spectrometric measurements were started in Atomki using a triplequad ICP-MS 8800 spectrometer of Agilent. The collision/reaction cell is located between two quadrupol units of the spectrometer. This design allowes high resolution MS/MS measurements, since mass interferences of isobar molecule ions can be removed by the collision gases. The typical measurable concentration range is ng/l – ug/l. Either concentration or isotope ratio of all the periodic table elements (except gases) could be measured with this method. A new method has been developed for determining elements (e.g. Ag, As, Th, U) occuring in low concentration levels in surface and groundwaters, and As in biological materials. Concentration of gadolinium (used as medical concrast agent) was measured in the effluent waste water from the Clinics of the University of Debrecen.

The aerosol pollution was studied during a smog alarm period in Debrecen, in November, 2011. An intensive sampling campaign was carried out with high time and size resolution using a streaker and a 9-stage cascade impactor sampler. The elemental composition of the 350 samples was determined by PIXE analytical method, the sources of the aerosol pollution

were identified with the help of PMF receptor modelling. In cooperation with the Hungarian Meteorological Service the tendencies of the fine and coarse aerosol components and sources were studied as well as their dependence on the mixing layer height and other meteorological parameters. Domestic heating was found to be the major source of the aerosol pollution, and its contribution was the highest when the mixing layer height was the smallest.

b) Dialog between science and society

Atomki had five significant fields of activities reaching the public in 2013: the dissemination project, Physicists' Days, Researchers' Night, Visitor Center and visiting groups coming to the institute.

The full title of the dissemination project (TÁMOP-4.2.3-12/1/KONV-2012-0057) is Distribution of Atomki's Scientific Results; the short title is Understandable-Available Physics. Its most popular program is traveling physics; young scientists of Atomki give unconventional physics lectures with interesting experiments in 10 high schools in the underprivileged regions around Debrecen. The topic changes every half a year; in the spring the lecture was about water as 2013 is the International Year of Water Cooperation, in the autumn it was about the natural protection systems of the Earth as the ozone layer was discovered 100 years ago. The total number of the audience was 1454. Both type of lectures were recorded and the video is available on the internet for other schools and for all the interested people.

Well understandable articles have been regularly printed about Atomki, its researchers and their scientific activities mainly in national daily papers, due to a scientific journalist employed in the project. In addition, the researchers themselves write many popular articles and appear in documentary radio and television programs.

The Researchers' Night was traditionally a successful meeting with science in September. The lecture hall was full for the talk about the neutrino. After the talk the public could get to know interesting games in the institute yard in the event with a title „Physics around us".

An important event in October is connected also with the neutrino: the main building of MTA Atomki became a European Physical Society Historic Site. It was this building in which the nuclear physics experiments for the confirmation of the existence of neutrino were performed by Sándor Szalay and Gyula Csikai in the autumn of 1956. The Debrecen neutrino experiment laid a brick of the foundation of modern physics. A nice table at the entrance of Atomki reminds people walking on the Bem square in Debrecen this event.

The Physicists' Days in Atomki was organized for the 34th time, its title was 2013 – The Year of Higgs Boson. This program was moved from March to November thus joining to campaign Research Institutes with Open Doors in the frame of Celebration of Hungarian Science. The lectures in particle physics were attended by primary school students and seniors as well, altogether by 289 during the four days. In the morning of these days, school groups from Debrecen and its surroundings, even from Transylvania came to see some of the 23 different unconventional physics lectures; they spent 1088 visitor hours in total. In the frame of the open day, some of the Atomki laboratories could be visited.

Due to the financial support of the Hungarian Academy of Sciences, Atomki Visitor Center was installed and opened on the first day of Physicists' Days. There are interactive instruments presented here. The Visitor Center will play an important role in the program of visiting groups arriving at the institute during the whole year. 371 visitors – primary, secondary school and university students, interested adults – came in 16 groups and spent 753 visitor hours in Atomki in 2013.

III. A presentation of national and international relations in 2013

In the national cooperations of the institute the connection with the departments of the University of Debrecen and with the Wigner Physics Research Center have the most important role, but the cooperation are wide also with other institutions. The connections appear also in the organization of scientific events.

On 17th of May 2013 an interdisciplinary workshop was organized on research results not only for experts but also for students and teachers with a title "Investigation of waters with isotopic methods in the MTA Atomki".

Between 21- 24th of August 2013 the Hungarian Meeting of Physicists was organized by the institute together with the Roland Eötvös Physical Society and the Institute of Physics of the University of Debrecen. The triannual meeting is the largest conference of the Hungarian physicists. The venue of the event was partly the institute partly the university.

The XI. Hungarian Aerosol Conference was organized in the Atomki in Debrecen by the Hungarian Aerosol Society and the institute on 28-30th of October 2013. The scientists working in aerosol research organize this conference every 2-3 years.

The institute preserved its positions in the higher education, and strenghtened its traditional links with the University of Debrecen. In addition, Atomki researchers delivered lectures at the University of Szeged. In the reported period of 2013, Atomki researchers held 919 lessons in the framework of 49 courses at. The number of the practical classes were 486 within 28 courses. Overall 38 researchers were involved in higher education activities. Besides the involvement in undergraduate teaching, the institute has a remarkable educational activity in doctoral schools. Eight of the principal members of the Physics Doctoral School at the University of Debrecen are Atomki researchers. During the reported period, 17 graduate students, 8 MSc undergraduates, 8 BSc undegraduates and 7 research students worked in the institute, and 3280 hours were spent on supervising them. The granting system of Researcher Student scholarship, in which the university students participate in the research work, continued in the insitute. Six students enrolled in the spring, and six in the autumn semester.

International connections are essential elements for successes of the research. Intensity of the cooperations is well reflected also in the inernational meetings, workshops, events.

A successful international scientific workshop was organized by the institute with the title „Open problems and future directions in heavy element nucleosynthesis". In the meeting on 10-12nd of April 2013 participated 31 foreign and 10 Hungarian physicists. After the Garching (2009) and Istanbul (2011) meeting the Debrecen workshop was the third event of the series of the nuclear astrophysics p-process studies.

The 65th session of the Nuclear Physics Committee of the European Physical Society was held in Atomki on 19-20th of April 2013.

In the frame of a training program on 17-21st of June 2013 foreign participants could listen to lectures of Atomki scientists about radioactive nuclides occuring in food.

The External Advisory Board of Atomki held its annual meeting in the institute on 1-2nd of September, 2013, where the activity of the Theoretical Physics Section was discussed.

The Department of the Theoretical Physics of the University of Debrecen and the Atomki were the organizers of the V. Hungarian-Japan Bilateral Workshop, which was held 9-12th of September and the problems of statistical physics were discussed on the meeting.

In the Debrecen activity of foreign scientists it was an important part also in 2013 the work in the frame of the transnational access project CHARISMA, an EU FP7 program. Saving the cultural heritage is a priority in the European Union. Within the framework of this project 6 foreign researchers were hosted by the institute from Czech Republic, France and Poland.

Some of the foreign researchers visited Atomki for longer periods of time. A researcher in nuclear astrophysics from the University of Basel continued his theoretical work in Atomki in a two months period. Another researcher from Kocaeli University (Turkey) worked 8 months on experimental tasks of the same field. Another researcher from Kocaeli University worked in environmental physics studies for 6 months. A researcher from NSF Arizona AMS Laboratory spent 4 months in the Atomki and worked on a ^{14}C-dating topic. His work was the continuation of his longer stay here in the last year. A scientist from Missouri University made theoretical physics studies in his 8 month stay in Atomki.

IV. Brief summary of national and international research proposals, winning in 2013

Domestically, Atomki received the largest support from the National Development Agency (NDA), the Radioactive Waste Management Inc, the Hungarian National Research Foundation (OTKA), while the highest international funding came from the organizations of the European Union. The institute is a participant of seven TÁMOP projects.

37 of the tenders and scientific grants of the institute was worth above 10 MFts and 26 was worth above 20 MFts in 2013. These latter 26 applications will be listed below, indicating the amounts actually transferred to Atomki, and their proportion for the year 2013.

NDA: Complex development in building energetics, 324997 eFt – 7662 eFt
NDA: Advanced imaging system, 106550 eFt
NDA: Communication protocols, 224327 eFt
NDA: Application of pulsed lasers, 19144 eFt – 8810 eFt
NDA: Future Internet Research, 49988 eFt– 4765 eFt
NDA: Preparation in the domestic ELI project, 60343 eFt – 18951 eFt
NDA: Dissemination of the results of Atomki, 99190 eFt – 39484 eFt
NDA: Solders safe for environment, 45211 eFt – 12586 eFt
NDA: Special fundamental research topics in biology and chemistry, 57600 eFt – 29556 eFt
Paks Nuclear Power Plant Ltd.: Difficult to measure isotopes, 47620 eFt – 12190 eFt
Radioactive Vaste Dep. Ltd.: Püspöksz. RHT area. Samples exam., 108788 eFt – 17523 eFt
NKTH– OTKA: The 3He + 4He reaction in the Sun, 24000 eFt – 2762 eF
OTKA: Nucleosynthesis of heavy elements, 21998 eFt – 6941 eFt
OTKA: Hungary in the CMS experiment of the LHC, 35872 eFt – 8968 eFt
OTKA: Correlations in the atomic nucleus, 31008 eFt – 5952 eFt
OTKA: Microchannels made with proton beam, 34418 eFt – 19574 eFt
OTKA: Development of neutron detectors, 29985 eFt – 5028 eFt
OTKA: Correlations in photoionization, 27744 eFt – 18936 eF
EU: The future's laboratory, 66262 EUR – 28983 EUR
EU: Development of artificial diamond-based detectors, 10040 EUR
EU: Development of E+ E- detectors, 79500 EUR – 25496 EUR
EU: EURATOM Fusion Training, 144928 EUR – 10924 EUR
EU: Tritium education program, 48000 EUR
EU: Collective excitations in atomic ionization, 100000 EUR- 15000 EUR
EU: Astrophysical p-process, 750000 EUR- 113745 EUR

EU: CHARISMA, 246446 EUR – 78345 EUR

note: eFt means 1000 Hungarian Forints

V. List of important publications in 2013

1. Bruckmann F, Endrődi G, Kovács TG: Inverse magnetic catalysis and the Polyakov loop. J High Energy Phys, (4): Paper 112. 22 (2013) http://arxiv.org/abs/1303.3972

2. Brunner N, Navascues M, Vértesi T: Dimension Witnesses and Quantum State Discrimination. Phys Rev Lett, 110 (15): 150501. 4 (2013) http://arxiv.org/abs/1209.5643

3. Cseh J, Kato K: Multichannel dynamical symmetry and cluster-coexistence. Phys Rev C, 87 (6): Paper 067301. 4 (2013) http://arxiv.org/abs/1302.0381

4. Csige I, Szabó Zs, Szabó Cs: Experimental technique to measure thoron generation rate of building material samples using RAD7 detector. Radiation Measurements, 59: 201-204 (2013) http://real.mtak.hu/8517/

5. Csige L, Filipescu DM, Glodariu T, Gulyás J, Günther MM, Habs D, et al. (13) Krasznahorkay A: Exploring the multihumped fission barrier of ^{238}U via sub-barrier photofission. Phys Rev C, 87 (4): Paper 044321. (2013) http://arxiv.org/abs/1302.3425

6. Guastalla G, Dijulio DD, Górska M, Cederkäll J, Boutachkov P, Golubev P, et al. (66) Algora A, Dombrádi Zs,Sohler D, Vajta Z: Coulomb excitation of Sn^{104} and the strength of the Sn^{100} shell closure. Phys Rev Lett, 110 (17): Paper 172501. 5 (2013) http://real.mtak.hu/9056/

7. Hornyák I, Kruppa AT: Coulomb-distorted plane wave: partial wave expansion and asymptotic forms. J Math Phys, 54: Paper 053502. 7 (2013) http://arxiv.org/abs/1304.6247

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10. Kövér L: Energy loss structures in HAXPES spectra of solids. J Eelectron Spectrosc, 190 (Part B): 144-152. (2013) http://real.mtak.hu/10278/

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12. Kuti I, Timár J, Sohler D, Paul ES, Starosta K, Astier A, et al. (36), Dombrádi Z, Nyakó BM, Tornyi TG, Zolnai L: Medium- and high-spin band structure of the chiral candidate La-132. Phys Rev C, 87 (4): Paper 044323. 10 (2013) http://www.csnsm.in2p3.fr/IMG/pdf/physrevc.87.044323.pdf

13. Lepailleur A, Sorlin O, Caceres L, Bastin B, Borcea C, Borcea R, et al. (22) Sohler D: Spectroscopy of F26 to probe proton-neutron forces close to the drip line. Phys Rev Lett, 110 (8): Paper 082502. 5 (2013) http://arxiv.org/abs/1301.5803

14. Lévai G: Semimicroscopic algebraic description of a clustering in Ne-22. Phys Rev C, 88 (1): Paper 014328. 12 (2013) http://arxiv.org/abs/1307.3007

15. Minezaki H, Oshima K, Uchida T, Mizuki T, Rácz R, Muramatsu M, et al. (11) Biri S: Synthesis of Fe-C-60 complex by ion irradiation. Nucl Instrum Meth B, 310: 18-22. (2013) http://real.mtak.hu/10280/

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17. Neuróhr K, Csik A, Vad K, Molnár G, Bakonyi I, Péter L: Near-substrate composition depth profile of direct current-plated and pulse-plated Fe-Ni alloys. Electrochim Acta, 103: 179-187 (2013) http://arxiv.org/abs/1402.3943

18. Rauscher T, Dauphas N, Dillmann I, Fröhlich C, Fülöp Z, Gyürky G: Constraining the astrophysical origin of the p-nuclei through nuclear physics and meteoritic data. Rep Prog Phys, 76 (6): Paper 066201. 38 (2013) http://arxiv.org/abs/1303.2666

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20. Sarkadi L, Herczku P, Kovács S T S, Kövér Á: Multiple ionization of rare gases by hydrogen-atom impact. Phys Rev A, 87 (6): Paper 062705. 10 (2013) http://real.mtak.hu/8631/

21. Tárkányi F, Takács S, Ditrói F, Hermanne A, Ignatyuk AV: Activation cross-sections of longer-lived radioisotopes of deuteron induced nuclear reactions on terbium up to 50 MeV. Nucl Instrum Meth B, 316: 183-191 (2013) http://arxiv.org/abs/1303.6417

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