INSTITUTE FOR NUCLEAR RESEARCH
4026 Debrecen, Bem tér 18/c, 4001 Debrecen, Pf. 51.
Tel: 06-52-509200, Fax: 06-52-416181
E-Mail: director@atomki.mta.hu; Webpage: http://www.atomki.mta.hu

I. Main duties of the research unit in 2014

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 2014
a) Outstanding research and other results

Quantum Physics

Researchers constructed multipartite Bell inequalities involving only two-body correlators which are capable of detecting nonlocality and showed that these correlations are accessible experimentally by means of measuring global spins with high precision. Ultracold atoms or systems of atoms trapped in nanostructures are promising experimental candidates for the implementation. This study may pave the way to experimental detection of nonlocality in quantum many-body systems. The so-called SWAP method has been developed in the device-independent framework, which refers to the fact that tomography of quantum states can be performed on the sole basis of the observed statistics coming from violation of a Bell inequality. The SWAP method has been applied to hitherto impossible cases such as robust self-testing of multipartite quantum states.

Systematic investigation of a general class of PT-symmeric potentials was performed. These potentials are typical examples for pseudo-hermitian quantum mechanical systems, which are beyond the traditional hermitian constructions of quantum mechanics, however, they have several characteristics in common with hermitian systems. Complex potentials possessing real energy eigenvalues are among them. Their importance is shown by the experimental verification of the occurrence of PT symmetry in nature, as well as its spontaneous breakdown. The mentioned investigation of the Natanzon potential class helps understanding pseudo-hermitian systems. This potential class contains most known solvable PT-symmetric potentials. As a new result, criteria were formulated for the possible structure of the energy spectrum, including also conditions for the spontaneous breakdown of PT symmetry.

Strictly finite-range (SFR) potentials are exactly zero beyond their finite range. Single-particle energies and densities, as well as S-matrix pole trajectories, are studied in a few SFR potentials suited for the description of neutrons interacting with light and heavy nuclei. The SFR potentials considered are the standard cutoff Woods-Saxon (CWS) potential, the SV potential [Phys. Rev. C 77, 037302 (2008)] and the SS potential [Int. J. Mod. Phys. E 21, 1250067 (2012)]. The parameters of these latter potentials were set so that the potentials may be similar

to the CWS shape. The trajectories are compared with a benchmark for which the starting points (belonging to potential depth zero) can be determined independently. For the CWS potentials some trajectories show irregular shapes, while for the SV and SS potentials all trajectories behave regularly.

The similarities and differencies between the applications of group theory for the classification of the elementary particles and nuclear states have been discussed, as initiated by Wigner. Particular attention was paid to the role of the represenations of the inhomogenous Lorentz-group in particle phyisics, to the U(4) group in both disciplines, and to the classification of the nuclear states in terms of the U(3) symmetry.

Particle Physics

The long shutdown of the LHC at CERN after the discovery of the Higgs boson gave possibility also for Atomki scientists to make further improvements at the CMS detector system. The position monitoring system of the barrel of the muon detector was developed by improving accuracy and reliability. The installation of new items has been completed, their effectiveness was confirmed. The data collected in the first running period of LHC was analysed and the hit efficiency of the pixel detector was measured. Using this measurement a simulation of the dynamic inefficiency of the detector was created. The simulation was tuned for the expected beam conditions in 2015.

The measurement of temperature and relative humidity is vital at the Silicon Tracker of CMS. The polyimide coated thermo-hygrometers installed in the CMS detector have been constantly read out during their first year of operation. The Atomki scientists are involved in the analysis of the measured data and the development of the connected algorithms. They are also involved in the development of a new kind of optical hygrometers based on LPG technology giving much higher sensitivity. A new position monitoring system concept for the GE1/1 detector was developed in collaboration with the Wigner RCP based on the experience obtained in the application of FBG fiber optic sensing technique. The full concept has been approved by the GE1/1 collaboration.

A new method for optimization has been worked out based on the requirement for the absence of spontaneous symmetry breaking and it has been used to optimize the regulator-dependence of functional renormalization group equations in the framework of the sine-Gordon model. The efficiency of the hyperthermic treatment by magnetic nanoparticles has been studied. Furthermore, a brief overview of the possible theoretical approaches for the determination of the QED fine structure constant has been written.

The ν critcal exponent of the Anderson transition in quantum chromodynamics (QCD) was determined. ν is the exponent characterizing the divergence of the correlation length at the transition. It was found that its value is compatible with that of the three dimensional Anderson model. This shows that the two transitions are in the same universality class. This result was published in Phys. Rev. Lett. and the paper was awarded the "Editors' Suggestion" label. A review paper on the Anderson transition in QCD was also published.

Nuclear Physics

An array of Parallel Plate Avalanche Counters (PPAC) for the detection of heavy ions has been developed. It was designed to be used in conjunction with the SiRi array of ΔE-E silicon telescopes for light charged particles and fits into the CACTUS array of large-volume NaI scintillation detectors at the Oslo Cyclotron Laboratory. The low-pressure gas-filled PPACs are sensitive for the detection of fission fragments, but are insensitive to scattered beam particles of light ions or light-ion ejectiles. The powerful combination of SiRi, CACTUS, and

PPAC provides new research opportunities for the study of nuclear structure and nuclear reactions in the actinide region.

Gamow-Teller (GT) transitions in atomic nuclei are sensitive to both nuclear shell structure and effective residual interactions. The nuclear GT excitations were studied for the mass numbers *A*=42, 46, 50, and 54 "*f*-shell" nuclei in (^{3}He, *t*) charge-exchange reactions. In the ^{42}Ca→^{42}Sc reaction, most of the GT strength is concentrated in the lowest excited state at 0.6 MeV, suggesting the existence of a low-energy GT phonon excitation. As *A* increases, a high-energy GT phonon excitation develops in the 6–11 MeV region. In the ^{54}Fe→^{54}Co reaction the high-energy GT phonon excitation mainly carries the GT strength. The existence of these two GT phonon excitations are attributed to the 2 fermionic degrees of freedom in nuclei.

Nuclear chirality is a new type of spontaneous symmetry breaking. A new aspect of this phenomenon, namely the multiple chiral doublets, has been studied. Three sets of chiral doublet band structures have been identified in the ^{103}Rh nucleus. The properties of the observed chiral doublet bands are in good agreement with theoretical results obtained using constrained covariant density functional theory and particle rotor model calculations. Two of them belong to an identical configuration and provide the first experimental evidence for a novel type of multiple chiral doublets, where an "excited" chiral doublet of a configuration is seen together with the "yrast" one. This observation shows that the chiral geometry in nuclei can be robust against the increase of the intrinsic excitation energy.

Within the framework of the EUROBALL - RIKEN collaboration the research was focused mainly on the region beyond ^{132}Sn. Change of the single particle energies has been studied as a function of the proton or neutron numbers. From the energy of the $p_{3/2}$ state in ^{131}In conclusion on disappearance of the Z=38,40 subshell closure was deduced, while from isomer spectroscopy of ^{136,138}Sn the missing N=90 subshell closure was concluded. From the study of the excited states in ^{126}Pd the role of the tensor force on the energy of the neutron $h_{11/2}$ state has been analyzed.

Reactions involving alpha particles play an important role in various processes of heavy element nucleosynthesis, like in the astrophysical gamma-process. The theoretical description of these reactions is hampered by the lack of precise knowledge of the low energy alpha-nucleus optical potential. To study this potential, the cross section measurement of a (p,α) reaction has been used. By the study of the ^{64}Zn(p,α)^{61}Cu reaction the alpha-nucleus optical potential could directly be studied at astrophysically relevant energies. The results provide a direct evidence that the optical potentials used in astrophysical calculations are indeed incorrect which influences strongly the isotopic abundances obtained from the models.

A strong contradiction is found between the observed and calculated abundance of the ^{6}Li isotope created in the big-bang nucleosynthesis. Since this isotope is produced predominantly by the d(α,γ)^{6}Li reaction, the study of this reaction is highly important in order to resolve the abundance discrepancy. No experimental data was available for this reaction at all at energies relevant for the big-bang nucleosynthesis. Exploiting the unique possibilities offered by the LUNA underground facility, the cross section of this reaction has been measured for the first time at the relevant energies. The results confirm the large difference between observations and calculations. The solution of the primordial ^{6}Li problem will likely require therefore nonstandard physics.

The modelling of the heavy, stable proton-rich isotopes, the so-called p isotopes, is based on reaction network studies and the necessary cross sections are provided by the Hauser-Feshbach statistical model. In the A >150 mass region there is a lack of experimental data, the precision of the predicted cross sections in this mass region were checked by the simultaneous

study of the $^{162}Er(\alpha,\gamma)^{166}Yb$ and $^{162}Er(\alpha,n)^{165}Yb$ reactions. The fact that the alpha capture cross sections were measured also below the (α,n) threshold for the first time in this mass region opened the opportunity to study directly the alpha+nucleus potential. It was found that – in order to reproduce the experimental data – a Fermi type function had to be added to the imaginary part of the alpha+nucleus optical potential.

Applied Nuclear Physics

Results obtained earlier were further evaluated as well as published, measurements were carried out on sodium target, and the differential DIGE method was introduced for depth profiling. The published papers contain the newly developed experimental set-up which allows the determination of nuclear reaction cross sections with the required precision, as well as the gamma-ray and particle production cross section data for ^{12}C, ^{14}N, ^{28}Si isotopes (19 cross section data sets). The data are available in the IBANDL database and, in the case of gamma-ray production cross sections as recommended values contribute to the quantitative elemental analysis with the Particle Induced Gamma-ray Emission method.

High aspect ratio, straight and tilted micropillars were fabricated in PDMS polymer by Proton Beam Writing method. The microstructures were created by irradiating the polymer with focused proton beam, by which, the irradiated area became cross-linked. The rate of the solidification depends on the deposited ion fluence. Furthermore, physicochemical properties, such as adhesion, refractive index or elastic modulus also change due to ion irradiation. This method makes the possibility to create microstructures with tunable properties, which can be useful in many applications, like lab-on-a-chip devices, high surface applications, catalysis, biomedical applications, directional adhesive surfaces.

^{64}Cu and ^{55}Co PET-radioisotopes for labelling were produced from natural Ni metallic targets by using the proton beam of the MGC-20 cyclotron. The studies are running in collaboration with SOTE and Technical University, Budapest. The radionuclidic purity and the very high specific activity of the separated radioisotopes make it possible to investigate the quantity and density of the specific receptors on the cell-membranes of living organisms. In order to transport the PET-isotopes into the targeted area the affibodies (Liposoma and intracellular vesiculum) were labelled with ^{64}Cu and ^{55}Co. The labelled affibodies are suitable for pre-clinical PET investigations.

To produce terbium isotopes for medical applications mechanically stable gadolinium layers were produced. A very small volume electroplating cell was used in order to provide suitable Gd electrolyte concentration by using enriched material. Uniform and sticky Gd layers were made up to a thickness of 3 mg/cm^2. These samples withstand 18 MeV proton beam up to 100 nA irradiation without any damage.

Study of charged particle induced reactions has been continued on rare-earth target materials, by assessing and publishing new experimental cross-section data. The investigations contribute to establish reference databases and developments of proper theoretical models and include the practical applications of the data. p-, d- and ^4He induced nuclear reactions were investigated on Be, Al, V, In, Nb, Mo, Pd, Rh, Au, W and Hg targets. The absolute amplitude of the $^{100}Mo(p,2n)^{99m}Tc$ nuclear reaction was also determined. The Atomki scientists played a decisive role in CRP projects initiated by the International Atomic Energy Agency and participated also in the work of NRDC by compiling experimental data for the EXFOR database.

Spectrometry and dosimetry measurements were done with quasi-monoenergetic d+D neutrons at Ed = 9.62 MeV deuteron energy. The Atomki QM-FNS neutron source by the MGC-20 cyclotron was used. A scintillation detector with NE-213 scintillator and digital

signal processing were used for neutron-gamma discrimination. One goal of the measurements was the testing of the applied algorithms. The Monte Carlo method used for simulating the irradiations was also validated. Relative neutron sensitivity of a Mg-Ar ionization chamber was measured, which is widely used for monitoring radio-biological neutron irradiations.

New irradiation devices were developed for the newly emerging sample types, which were also tested and used in real circumstances. Based on the collected experiences the new devices were fine-tuned in order to achieve optimum irradiation parameters. They have also optimized the application of less frequently used radio-isotopes, and further developed an activation method using low abundance sample elements. The measurements were also optimized for using Free Handling Limit activities. They extended the existing literature and the databases maintained by the IAEA were extended with further nuclear reaction cross section data, mainly in the field of proton and deuteron induced nuclear reactions, but some new results for alpha and ^{3}He induced reactions were obtained, too.

MiniPET-3 is a small and high resolution Positron Emission Tomograph camera, which was built and installed in Atomki originally for small animal investigation in 2013. It is, however suitable also for monitoring of chemical surfaces in catalysis processes. Referring to the research results (ChemPlusChem, 78, 2013, 830–836) of the institute, the Department of Chemical Engineering, Technical University, Eindhoven (The Netherlands) contacted Atomki and asked for a cooperation. The Dutch university has developed special catalysts and their effectiveness and deactivation process can be studied by PET camera. The catalysis processes have been optimized for PET imaging.

Atomic collision processes

The collisional processes may significantly depend on the sign of the charge of the projectiles. So, experiments with particles and their antiparticle pairs provide a sensitive test for atomic collision theories. Due to the development of accelerators, significant intensity increase may be expected for example in the case of antiprotons in the near future. This justifies the following theoretical investigations. In one of the studies fully differential cross sections for ionization of the atomic hydrogen by antiproton (and proton) impact was calculated using the classical trajectory Monte Carlo method and quantum mechanical continuum-distorted-wave-eikonal-initial-state model. By examining individual particle trajectories, it was found that the motion of the light electrons and the heavy nuclei is coupled very weakly. In another investigation, the single and double ionization of the He atom was calculated by antiproton impact for projectile energies ranging from 3 keV up to 1000 keV. Accurate total cross sections were obtained by directly solving the fully correlated two-electron time-dependent Schrödinger equation. Ab initio doubly differential cross sections for single ionization were also calculated at 10 and 100 keV impact energies. In these differential cross sections, the binary-encounter peak and the anticusp minimum are identified. Furthermore, the importance of the postcollisional electron-projectile interaction at low antiproton energies, which significantly suppresses electron emission in the forward direction, was shown.

The recent development of the magneto-optical trap reaction-microscope has opened a new chapter for detailed investigations of charged-particle collisions from alkali atoms. Using perturbative and coupled-channel methods, it was shown that energy-differential cross sections for ionization from the outer-shell in energetic H^{+}, O^{8+} -Li collisions can be readily explained with the single-active-electron approximation. Understanding of K-shell ionization, however, requires incorporating correlated many-electron effects.

Molecular fragmentation leading to the formation of negatively and positively charged hydrogen ions in 7-keV OH^{+} + Ar collisions is investigated experimentally. The most striking

finding is that negative and positive hydrogen ions are emitted with very similar angular dependences. Also, the kinetic energy distribution of the H^+ fragment shows strong similarities with that of the ejected H^- ion. The kinematics of the emitted H core is found to be essentially driven by its Coulomb scattering on the atomic target. Though the electron capture process is complex, it is shown that the relative population of the different final charge states of the outgoing fragments can be described by simple statistical laws.

Single ionization of noble gas atoms and hydrogen molecules by linearly polarized synchrotron radiation has been studied by employing angle- and energy-resolved photoelectron spectroscopy. The measurements were carried out in the plane defined by the momentum and polarization vectors of the photon. During the determination of the anisotropy parameters from the experimental DDCS a symmetric and asymmetric angular distribution were observed relative to the momentum of the photon. The asymmetry values were measured for outer *s* -shells of He, Ne, Ar and Xe atoms at two synchrotrons and the experimental data agree well and differ from zero for all targets. Furthermore similar investigations were carried out for the outer *p*-shells of Ne, Ar, Kr and Xe atoms. The asymmetry parameters (A_{LR}) were negative for the *p*-shells while it was positive for the *s*-shells. The photonenergy dependence of the A_{LR} parameter was determined in wide energy range (100-460 eV) and for several shells. It was found that the A_{LR} function is an oscillating function.

The photon-ion merged-beams technique has been employed at the new Photon-Ion spectrometer at P04 beam line of PETRA III synchotron (DESY, Hamburg) for measuring multiple photoionization of Xe^{q+} (q = 1–5) ions in the photon energy range of 3*d* resonant excitation (500-1200 eV). The measured cross sections exhibit progressively more resonance features as the primary ion charge state is increased from 1+ to 5+. Single-configuration Dirac–Fock calculations agree quantitatively with the experimental cross sections for non-resonant photoabsorption, but fail to reproduce all details of the measured ionization resonance structures.

Applications in Atomic Physics, Solid State Physics, Surface Sciences

In order to increase the long term-operation stability of palladium based catalysts applied in direct formic acid fuel cells, the Pd-ZrO2 catalyst supported on the multiwall carbon nanotubes (MWCNTs) was prepared and thermo-chemically treated. These catalysts were tested for formic acid electro-oxidation in a fuel cell, and their chemical composition and structure were characterised using XPS, STEM, HR-TEM and XRD techniques. It was found that following synthesis, the voltage of the cell was oscillating during the operation of the Pd-ZrO2/MWCNTs catalyst, resulting in a significantly higher deactivation resistance than in the case of the Pd/MWCNTs catalyst. This may be attributed to the “self-cleaning” mechanism of the poisoned Pd catalyst by carbon monoxide through electrochemical oxidation of adsorbed CO to CO2 (gas).

The surface and volume plasmon energy loss spectra and their dependence on the emission depth measured from the surface was modeled in the case of Li 1s photoelectrons excited from a Li single crystal. Applying the quantum Landau formula, the elastic scatterings of the photoelectrons before and after the energy loss, as well as the multiple plasmon excitations were fully accounted for. Elastic electron scatterings are significantly modifying the depth profile of the intensity of the Li 1s plasmon peak. The effect of elastic electron scattering changes the relative intensity of the surface and bulk plasmon peaks as well, in the case of Li this ratio was found to be slightly higher, than without accounting for elastic scattering, indicating that the Li atoms are weak scatterers and because of the defocusing effects the contributions from shallow depth emitters are dominant only.

The concentration depth profiles of coloured surface layers of hot dip galvanized steel sheets have been examined using Secondary Neutral Mass Spectrometry (SNMS). The zinc bath alloyed with 0.15 w.t.% titanium content can result in different coloured surfaces, during the cooling of the samples in ambient air. It was shown that the surface oxide layer of different thicknesses caused a discoloration of samples, as a result of diffusion and oxidation of Ti atoms. The experiments showed that the surface colour varied from yellow to light blue depending on the temperature of the bath. X-Ray Photoelectron Spectroscopy (XPS) was also used to study the phase of the oxide layer, which was identified as TiO_2.

Applying secondary neutral mass spectrometry and X-ray diffraction methods the solid-state reaction in Pt/Fe and Pt/Ag/Fe thin films has been studied. It was shown that during annealing the bulk diffusion processes were still frozen, homogeneous reaction layers of FePt and FePt with about 10 at.% Ag, respectively, were formed. Corresponding depth profiles of the element concentrations revealed a strong evidence that the formation mechanism is based on the grain boundary diffusion induced solid-state reaction in which the reaction interfaces develope perpendicularly to the original grain boundary. X-ray diffraction shows that in both thin-film systems after the solid-state reaction the ordered L10 FePt phase, which is the requested phase for future magnetic data storage applications, is also present.

Environmental Physics

As a part of complex study of the Bohemian Massif, K-Ar ages have been established for the melilitic rock series (79.5 – 61.3 Ma) and the monchiquite – camptonite rock series (30.9 – 23.0 Ma). In western Bohemia time-span of the weakly alkaline series (13.5 – 10.2 Ma) and the strongly alkaline series (18.3 – 6.25 Ma) have been determined. Ages of trachyandesites, trachytes and phonolites in the Ceske Stredohory Mts. range from 33.8 Ma to 23.1 Ma.

A novel method was introduced to apply selaed-tube graphitization method for AMS C-14 target preparation for samples with about 1 mg C size. This method is a good base for further developments of microgram sizes sample preparation as it use less chemicals (no TiH_2 applied). The novel method was optimized for 25-100 ug C sized samples of a MICADAS type AMS. Their results were presented at the 13th AMS scientific conference (Aux el Provance, France) and 2 papers were submitted to different scientific journals (Radiocarbon and NIMB).

Several multistacked gas fields, located in very different parts of Hungary, display a large variation in their gas composition. The shallow position of the mantle beneath the basement of the Pannoninan Basin System is responsible for the high heat flux. It facilitates that the CO_2 – intensely released from the ascending upper-mantle derived melts – could reach the basin system. The research resulted in a geochemical study of the main components and noble gases (mainly helium) of the multistacked Répcelak (CO_2– HC– N_2) and Mihályi (CO_2) fields. The vertical variations of gas composition in the Répcelak and Mihályi fields fit well with in-reservoir mixing of two end-members, a mantle-related magmatic CO_2 fluid and a N_2-rich HC-gas fluid of crustal origin. However, it is very likely that other processes modified to some extent the gas composition of the two fields. Carbon isotopic composition of the CO_2 of the samples studied agrees with both the carbonate decomposition and mantle degassing origins. It is very likely that the marked difference in helium isotopic composition between the neighbouring Répcelak and Mihályi fields also reflects this heterogeneity.

Using etched track type radon detectors, changed seasonally, it was found that the annual average ^{222}Rn activity concentration in the air of Rákóczi Cave (Aggtelek National Park, Hungary) is relatively low (3 $kBqm^{-3}$), it does not change significantly spatially but shows seasonal variation which is explained by natural ventilation pattern of the cave galleries in the winter season.

Radiocarbon in Dissolvad Inorganic and Organic Carbon (DIC and DOC) fraction of groundwater samples from a nuclear waste storage facility and a nuclear power plant was studied. Some cases the radiocarbon concentration in DOC was very different than in DIC and was higher than in natural materials. Nowadays nuclear environmental monitoring is focusing mainly on the DIC fraction in water bodies. New results show that it would be very important and useful to measure/monitor regularly also the C-14 in the DOC fraction from the groundwater around nuclear facilities. DOC and DIC together would give a more precise and realistic picture about the real C-14 impact of nuclear stations on the groundwater.

A novel, more effective Pd-Ag separation method was developed for ^{107}Pd studies of liquid radiocative wastes. In a stepped chemical degradation method Pd is collected in a water soluble form meanwhile Ag forms a solid precipitation which can be easly separated by filtration. Finally now it is possible to achieve the detection level around 1 Bq/dm^3 ^{107}Pd acitivty concentration which was desired to be able to investigate real waste of nuclear power plants.

Novel 8-channel liquid flow monitoring systems for living trees was set up and installed in the forest of the Síkfőkút Project of Debrecen University. Time trend of water flow and trunk diameter was monitored in case of several different maple and oak trees and their hybrids. This study gave a long trem monitoring dataset about the groving period of the trees when the weather was wet in that area. These data could help the understanding of the effects of climate change on the different type of trees in Hungary.

PM2.5 atmospheric aerosol is collected on weekly basis in Debrecen, Hungary since 2012. During the last 2 year in a continuous sampling action more than fifty aerosol samples were collected onto preheated quartz filters. In the course of analyses, besides the total carbon content, the specific 14C content values were measured on the samples using AMS and EA/IRMS techniques. Using a novel EA/IRMS setup it was possible to measure on-line the total carbon content of the aerosol samples. Contribution of the modern and fossil derived sources was evaluated to the total carbon content of the atmospheric aerosol. Based on the two-year long dataset regarding the radiocarbon concentration in the carbonaceous aerosols the dominance of the residential wood burning was observed. The proportions of biological sources relative to the fossil ones were fairly large (contemporary carbon fraction average 0.72) trough the whole 2 year sampling period but during wintertime heating periods obviously higher biomass peaks (wintertime contemporary carbon farction average ~0.8) were systematically observed in the air of Debrecen city.

b) Dialog between science and society

Activities of Atomki reaching the public in 2014 were: the dissemination project, Researcher's Night, Science on Stage, Physicists' Days and visiting groups coming to the institute.

The most popular program of the dissemination project Distribution of Atomki's Scientific Results – Understandable-Available Physics (TÁMOP-4.2.3-12/1/KONV-2012-0057) is Traveling Physics. Young scientists of Atomki gave unconventional physics lectures with interesting experiments in 10 high schools in the underprivileged regions around Debrecen. The topic changed every half a year; in the spring the lecture was about cold and warm as Fahreinheit created the first mercury thermometer 300 years ago, in the autumn it was about the energy as Leibniz declared the principle of the conservation of energy 300 years ago. The total number of the audience was 1523.

In the frame of the Popular-Science Day, scientific knowledge was transfered to high school students in Debrecen just before the start of the summer holiday. Beyond the lectures of Traveling Physics, they could hear interesting facts about stars, the power plants and chemical laboratories of nature. The audience counted 271 pupils.

The lectures of Traveling Physics and Popular-Science Day were recorded and the videos are 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 in county- and country-wide papers, due to a scientific journalist employed in the project. In addition, the researchers themselves have written many popular articles and appeared in documentary radio and television programs.

The Researcher's Night was a good chance for the audience of about 180 people to familiarize with particle physics and to virtualy visit the undergound laboratory in Gran Sasso.

The Hungarian selection of teachers for the international Science on Stage festival was organized in Atomki. Altogether 42 teachers presented new ideas in mathematics, physics, chemistry, biology and informatics. The local festival was attended by almost 200 children and adults.

The opening ceremony of Celebration of Hungarian Science in Debrecen was organized in Atomki due to the 60th anniversary of the institute. After the colourful lectures, the guests visited the laboratories and the exhibition about the 60 years of Atomki.

The Physicists' Days in Atomki was organized for the 35th time, this year in the field of energy. With this program, the institute joined to campaign Research Institutes with Open Doors in the frame of Celebration of Hungarian Science. The lectures about energy were attended by primary school students and seniors as well, altogether by 215 during the four days. In the morning of this week, school groups from Debrecen and its surroundings, even from Transylvania came to see some of the 27 different unconventional lectures; 63 lectures were given and 1645 visitor hours were spent in total.

In addition to the visitors above, 21 visiting groups came to see Atomki this year (primary, secondary school and university students, interested adults) and spent here 1446 visitor hours. The main attraction of the Visitor Center is demonstration of radioactivity and its properties; during the cryophysical demonstration visitors can see some phenomena taking place at very low temperature.

III. A presentation of national and international relations in 2014

The cooperations with the departments of the University of Debrecen and with the Wigner Physics Research Center had decesive role in the national connections of the institute, but the cooperations are wide also with other institutions.

Interdiciplinary workshops named „Cold-warm" and „Energy" were organized in Atomki 15th of May and 2nd of October 2014, respectively. The scientific background of the everyday problems was explained by Hungarian experts in interesting talks.

14th of November 2014 a scientific session was organized by the Laboratory of Environmental Studies in memory of the scientist Ede Hertelendi who deceased 15 years ago. The talks reflected the remembrance of the founder of the laboratory and showed a picture about the recent results of environmental research.

The institute preserved its positions in the higher education also in 2014, 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 2014, Atomki researchers held 1020 lessons in the framework of 58 courses. The number of the practical classes were 531 within 70 courses. Overall 40 researchers were involved in higher education activities. Besides the involvement in undergraduate teaching, the institute has a remarkable educational activity in doctoral schools. Seven of the principal members of the Physics Doctoral School at the University of Debrecen are Atomki researchers. During the reported period, 22 graduate students, 10 MSc undergraduates, 13 BSc undegraduates and 7 research students worked in the institute, and 3590 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 eight 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.

The XIII. Nuclei in the Cosmos conference was organized by Atomki 7-11th of July 2014. The conference is organized in every two years at different places of the world since 1990. After Germany and Australia it was Hungary that gave the venue of this international meeting of nuclear physicists, astrophysicists, cosmochemists. The inherent part of the conference is a school, which was organized in Atomki between 30th of June and 4th of July.

An other two-yearly conference was also organized in Debrecen in 2014. 13-18th of July the institute organized the International Conference on Atomic Collisions in Solids (ICACS – 26). The participants dicussed a wide range of the phenomena of the topic.

The External Advisory Board of Atomki held its annual meeting in the institute on 13th of October 2014, where the activity in atomic research and nuclear application was discussed.

A scientist from the Nuclear Research Center of Egypt spent more than half a year in the institute and worked in the field of application of cyclotron.

IV. Brief summary of national and international research proposals, winning in 2014

The first period of the operation of the new Tandetron type particle accelerator was finished. The accelerator was obtained in the frame of the infrastructure competition of the Hungarian Academy of Sciences. In the competition participated several research groups of the institute. A broad range of subjects of basic research and application is planned with the use of the accelerator in nuclear physics, nuclear astrophysics, atomic physics, ion beam analysis and micromachining.

30 of the tenders and scientific grants of the institute was worth above 10 MFts and 20 was worth above 20 MFts in 2014. These latter 20 applications will be listed below, indicating the amounts actually transferred to Atomki, and their proportion for the year 2014.

NDA: Application of pulsed lasers, 493440 e Ft – 4392 e Ft
NDA: Future Internet Research, 1577727 e Ft– 14040 e Ft
NDA: Dissemination of the results of Atomki, 99190 e Ft – 37142 e Ft
NDA: Special fundamental research topics in biology and chemistry, 57600 e Ft – 29556 e Ft
NDA: Intelligent functional materials, 793737 eFt – 41606 e Ft
NDA: Solders safe for environment, 603981 e Ft – 19793 e Ft

NDA: Preparation in the domestic ELI project, 60343 e Ft – 31583 e Ft
NDA: Communication protocols, 224327 e Ft – 27921 e Ft
NDA: Advanced imaging system, 160954 e Ft
Paks Nuclear Power Plant Ltd.: Environmental radio carbon, 20803 e Ft – 10555 e Ft
Paks Nuclear Power Plant Ltd.: Difficult to measure isotopes, 26150 e Ft – 14750 e Ft
EU: The future's laboratory, 2448339 EUR – 7627 EUR
EU: CHARISMA, 246446 EUR
OTKA: Dynamics of molecular collisions, 25792 e Ft – 9096 e Ft
OTKA: Open quantum systems, 21740 e Ft – 6108 e Ft
OTKA: Correlations in the atomic nucleus, 31008 e Ft – 5952 e Ft
OTKA: Development of neutron detectors, 29985 e Ft – 3369 e Ft
OTKA: Correlations in photoionization, 27744 e Ft – 3336 e F
OTKA: Microchannels made with proton beam, 34418 e Ft – 4948 e Ft
OTKA: Hungary in the CMS experiment of the LHC, 26904 e Ft

note: eFt means 1000 Hungarian Forints

V. List of important publications in 2014

Gyürky Gy, Fülöp Zs, Halász Z, Kiss G G, Szücs T:
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