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I. Main duties of the research unit in 2010

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 equipments and methods for fundamental and applied science. The institute participates in graduate education and takes on tasks in undergraduate education. The institute performs supplemental activities in the area of its fundamental activity.

II. Outstanding research and other results in 2010

a) Outstanding research and other results

Quantum Physics

Quantum correlations It has been shown that the detection efficiencies required for closing the detection loophole in Bell tests can be significantly lowered using quantum systems of dimension larger than two. A series of asymmetric Bell tests were introduced for which an efficiency arbitrarily close to 1/N can be tolerated using N-dimensional systems, and a symmetric Bell test for which the efficiency can be lowered down to 61.8% using four-dimensional systems. Experimental perspectives for our schemes look promising considering recent progress in atom-photon entanglement and in photon hyperentanglement.

Symmetries in quantum system The question of how much the states of N=Z nuclei are clusterized, or how much they have a shell-structure is an old and important problem of nuclear structure. Both the shell model and the cluster model provide us with a complete basis, therefore, any nuclear state can be expanded in shell or cluster states. In light of the recent phase-studies of quantum systems they can be considered as different phases of the finite nuclear matter. The expansions for the states of the ground-band of the ^{20}Ne and ^{24}Mg nuclei were investigated, by applying a microscopic approach. The ^{16}O+alpha(s) state could be regrouped into ^{16}O+nucleons, by varying a parameter of the wavefunction. The physical reason for this change is the increasing importance of the spin-orbit interaction. It turned out that in both nuclei the description of the experimental data requires wavefunctions which are close to category iii), i.e. good shell-model-like, or SU(3) cluster states.

Asymptotic properties of three exactly solvable PT-symmetric potentials were analyzed. The importance of this work lies in the fact that after a decade of theoretical studies, an experimental verification of the existence of PT symmetry has been achieved in physical systems (including the theoretically predicted spontaneous breakdown of PT symmetry). The experimental setup was a waveguide containing regions where loss and gain of flux occured in a setout prescribed by PT symmetry. These regions are naturally finite, therefore it was worthwhile to study similar exactly solvable systems. It turned out that although the real components of the Scarf II and Rosen-Morse II potentials are identical, their behaviour is different due to their asymptotically different imaginary component. The latter system, e.g., does not exhibit spontaneous breakdown of PT symmetry, irrespective of the magnitude of its

imaginary component. The properties of the Scarf II potential are qualitatively similar to those of the PT-symmetric Coulomb potential, although their general character is rather different.

Masses, or, equivalently, ground state energies of nuclei are very important basic quantities. For example, shell structure changes around drip lines or existence of new magic numbers beyond the heaviest known nuclei can be studied with the help of mass measurements. Global mass calculations have been carried out using the so called macroscopic-microscopic method invented by Strutinsky. In this approach the binding energy is the sum of two terms, and the key element is a curvature correction which is necessary to satisfy the self consistency condition. While in the standard method the curvature correction is achieved by multiplying a kernel by a polynomial, here two new non-polynomial curvature correction methods were introduced. The standard method is also modified replacing an infinite range kernel function by a finite one. The new methods provide significantly more stable results, even far from the valley of stability line, and they works well for lighter nuclei, too.

Particle Physics

Participation in CMS Collaboration The Muon Barrel Alignment system of the CMS detector were run from January 2010 continuously. Atomki researchers performed more than 3000 measuring cycles and participated in two coordinated measurement campaigns (in April and November). They also participated in development of a control system for measuring the temperature and vapour distribution inside the CMS detector and worked out the timing of the pixel detector.

Particle Physics Phenomenology The Atomki team continued the development of the theory of second radiative corrections of jet cross sections: they integrated the iterated singly-unresolved subtraction terms over the factorised phase space of the two unresolved partons.

Quantum Field Theory Phase diagrams of the two-dimensional multi-frequency sine-Gordon (SG) models defined on compact and non-compact spaces have been compared. It was shown that the high-energy behaviour of the two cases coincides, while the low-energy behaviour is different. Thus compactness does not influence the critical frequency at which the SG model has topological phase transformation because the latter is determined by the high-energy scaling behaviour.

Nuclear Physics

The β feeding probability of several fission fragments, which are important contributors to the decay heat in nuclear reactors, has been measured using the total absorption technique. A total absorption spectrometer has been coupled for the first time to a Penning trap in order to obtain sources of very high isobaric purity. The results solve a significant part of a long-standing discrepancy in the γ component of the decay heat for ^{239}Pu in the 4–3000 s range.

The nuclei ^{230}U and ^{232}U were populated in the compound nucleus reactions ^{232}Th(α,6n) and ^{232}Th(α,4n), respectively. Gamma rays from these nuclei were observed in coincidence with a recoil detector. A comprehensive set of in-band $E2$ transitions were observed in the lowest lying negative-parity band of ^{232}U while one $E2$ transition was also observed for ^{230}U. These allowed $B(E1;I\rightarrow I^{+}\text{-}1)/B(E2;I\rightarrow I\text{-}2)$ ratios are to be extracted and compared with systematics. The values are similar to those of their Th and Ra isotopes. The possibility of a tetrahedral shape for the negative-parity U bands appears difficult to reconcile with the measured Q_2 values for the isotone ^{226}Ra.

The feasibility of measuring g-factors in relativistic heavy fragmentation products was explored. The $J^{\pi} = 12^{+}$ isomer in ^{192}Pb with has been produced using the fragmentation of a 1AGeV ^{238}U beam. The results presented demonstrate for the first time that such heavy nuclei produced in a fragmentation reaction with a relativistic beam are sufficiently well spin-aligned. The measured value of the g-factor is in agreement with the previous results.

The first results have been published on the true ternary fission of ^{234}Pa. The ratio of the true ternary fission to the normal fission, depending on the geometrical arrangement of the detectors was found to be $\approx 10^{-5}$. The mass of the lightest fragment has been found 20-40 a.m.u. The connection of the effect to the cluster decay was also discussed.

Structure of the ^{44}S nucleus, having a magic neutron number, has been investigated at GANIL, France. In this nucleus an isomeric state with 2.6 μs lifetime has been observed. Form its electron and gamma decay properties the spin and deformation of the state have been determined. It has been shown that the order of the normal and intruder states changed in this nucleus, the deformed intruder state became the ground state of this nucleus, while the normal spherical is the isomeric state found in the referred work.

Structure of the light fragments originating from the ^{36}S+^{208}Pb deep inelastic collision has been studied in the Legnaro National Laboratory within the frame of an international collaboration. In the ^{33}Si nucleus lying next to the N=20 magic number intruder neutron states have been identified, in the ^{38}Cl nucleus evidence for core excitations has been found, while in ^{40}S the energy of the yrast states has been determined.

A measurement of the energy and spin of superdeformed states in ^{190}Hg, obtained through the observation of transitions directly linking superdeformed and normal states, using the EUROBALL-IV detector system, expands the number of isotopes in which binding energies at superdeformation are known. Comparison with neighbouring nuclei shows that two-proton separation energies are higher in the superdeformed state than in the normal state, despite the lower Coulomb barrier and lower total binding energy. This unexpected result provides a critical test for nuclear models. The researchers have shown that only those calculations can reproduce the experimental data which take into account collective quadrupole modes.

A complete kinematics measurement was performed in the iThemba LABS, South Africa, using the ^{6}Li(^{3}He,t) reaction at E_{lab} = 50 MeV to investigate the cluster structure of ^{6}Be. Decay modes of ^{6}Be were studied through the analysis of the energy and angular distributions of the break-up particles. To measure the type and energy (with detectors assembled in the Atomki) of the particles, a position sensitive detector system was used. The results indicate a rather pure three-body configuration for the 2^+ state of ^{6}Be. Two-body decay is observed above the first excited state but not firmly assigned to a ^{6}Be resonant state.

Non-yrast, medium-spin states of the ^{152,154,155}Gd nuclei have been studied using the AFRODITE gamma-array. It has been found that the bands built on the second 0^+ states in ^{152}Gd and ^{154}Gd, previously assigned as β-vibrational bands, do not show the expected properties of the beta-bands. The 0^+_2 states can rather be interpreted as second quasiparticle-vacuum states having their own gamma- and octupol-vibrational bands. This result contradicts to the previously widely accepted interpretation of the second 0^+ state in deformed nuclei.

Low energy cross sections of the ^{151}Eu(α,γ)^{155}Tb and ^{151}Eu(α,n)^{154}Tb reactions have been measured. Based on the experimental result, a factor of two reduction of the relevant reaction rates in p-process network calculations is recommended. Total reaction cross sections have been determined from elastic alpha-scattering data around the coulomb barrier. With a high precision experiment the uncertainty of the half-life of ^{133m}Ce has been reduced by almost two orders of magnitude.

The ^{25}Mg(p,γ)^{26}Al is a key reaction in the MgAl cycle of stellar hydrogen burning. The strengths of three low energy resonances have been measured with increased precision.

The proton capture cross section of both stable nitrogen isotopes has been measured and an R-matrix extrapolation to the astrophysical energies has been carried out.

Using the indirect Trojan Horse Method the strengths of astrophysically relevant low energy resonances have been determined.

Compilation and critical evaluation of the new experimental data on all the known nuclides belonging to the A=50 mass number have been performed. A list of adopted data has been given for all nuclides. The compiled and adopted data have been published in the ENSDF internet-based database. Similar compilation and evaluation work has been commenced for the nuclides belonging to A=129.

Applied Nuclear Physics

The angular spread of the nanocapillaries of nanoporous alumina by the method of ion transmission microscopy has been determined. Atomki researchers designed and created diffraction gratings and micro Fresnel lenses by proton beam writing in poly(dimethylsiloxane) (PDMS) polymer and investigated their working characteristics.

Seasonal variation and long-term tendencies of composition and sources of atmospheric aerosol characteristics to the East-Hungary region were determined for the time period 1993-2010. Five different sources of course fraction with Cl were identified. It was established that the concentration of particulate matter inside kindergartens and schools nearby heavy traffic roads exceeded the 24-hours limit recommended by WHO.

Elemental composition of sediments of the Tisza-Kraszna floodplain near Vásárosnamény was determined by ED-XRF, PIXE, F-AAS analytical methods. The effect on plants of the increased heavy metal concentrations was investigated with Sinapis Alba test.

Measurements with the scanning nuclear microprobe were provided for 7 foreign research groups within the framework of the Charisma EU FP7 I3 project filed of cultural heritage.

In cooperation with the Aquincum Museum an Atomki IBA team has analyzed a millefiori type archaeological glass found in Aquincum by SEM-EDX and micro-PIXE analytical methods for the first time. The application of Roman and Mesopotamian techniques was pointed out.

Studies proved that ZnO nanoparticles, extensively used in sun protection products, cannot penetrate into the skin affected by atopicdermatitis.

Measuring method and evaluation software was developed for studying radiation hardness of thin organic samples by real-time monitoring of hydrogen-loss, indicating molecular damage. Radiation hardness of organic foils (kapton, mylar, PDMS) was determined by the method.

The preparation of different radioisotopes have been investigated by proton induced nuclear reactions: ^{133}Ba on Cs target and Ir isotopes on enriched ^{192}Os target. The cross section data measurements of the nuclear reactions in E_p<66 MeV energy range was carried out in the frame of international collaboration (iThemba, South-Africa). A remarkable success was to separate ^{103}Pd from rhodium target with thermo-chromatography.

Within the framework of a Hungarian-Indian collaboration the study of *Se* species started in Hungarian soil and plant samples in 2010. The *Se* uptake of the sunflower and corn cultures was studied in collaboration with the Agricultural Center of the Debrecen University.

A method, based on the ICP-MS technique, was developed for the radiochemical determination of the beta emitting ^{36}Cl isotope, a hard-to-detect waste of nuclear power stations (Paks).

The catalytic behaviour of Cu- and Cr-modified SBA-15 mesoporous silica was studied by the conversion of methanol reagent labelled with ^{11}C. The numbers and extent of weak and strong bounds on the catalyst surface was determined by an upgraded detection method.

In 2010 the study of PET imaging technique for investigation of heterogeneous catalysis using ^{11}C-radioisotope labelled reagents was continued.

The Data Library of deuteron induced activation cross section for ”IAEA Nuclear Data Libraries for Advanced Systems: Fusion Devices: Fusion Evaluated Nuclear Data Library, FENDL 3.0” has been completed for the planning works of ITER and IFMIF.

An improvement of the description of the neutron energy dependence of the energy resolution of a neutron detector with NE-213 liquid scintillator was achieved via measurements and simulated via a Monte Carlo code.

Systematic investigations have proved the advantages of a home made Epithermal Neutron Analyzer (ETNA) for bulk hydrogen analysis as compared to the thermal neutron techniques. Results can contribute, for example, to the design and construction of instruments needed for the detection and identification of plastic anti-personnel landmines, explosives hidden in airline baggage and cargo containers via hydrogen contents as an indicator of their presence.

Classical molecular dynamics simulations have been performed for studying the development of atomic displacement cascades induced in beryllium (hcp-Be) crystals by primary knocked-out Be-atoms with $E \leq 80$ eV energies. The topic is important from the point of view of development of the future thermonuclear fusion reactors.

In 2010 Atomki reasearchers established the application of isotopes with activity under the Free Handling Limit (FHL). This simplified the complicated licensing and delivery processes. The irradiated samples could be transferred as simple package by post, using only limited shielding. This research has been carried out together with the Austrian AC2T institute. They have also elaborated the application of new isotopes for the investigation of parts containing the most common basic materials (Fe, Cu). Within a German cooperation we developed the using of Sb-120m isotope for investigation of tin containing materials

Within the framework of the new PHARMATOM project the renovation of the radiochemical laboratory has been started for the purposes of pharmaceutical research. In cooperation with the IAEA a 3 year-project for research and development of high performance gas and liquid targets for medical purposes is running.

Atomic collision processes

The phenomenon of the double ionization in 100 keV He^{2+} + He collision was studied. Calculations carried out in the continuum distorted wave (CDW) approximation showed that in the formation of the energy and angular distribution of the emitted electrons the final-state electron correlation plays a decisive role. The process of the electron capture into the continuum states of the projectile ion was investigated, too. This is the so-called two-electron cusp that had been previously proved experimentally in Atomki.

The dynamics of the three-body breakup process was studied in 75 keV p + H collision. Experimental data published recently in the literature were analyzed by applying the Classical Trajectory Monte Carlo (CTMC) method.

Multiple differential cross sections were calculated in classical (CTMC) and QM distorted wave approximations for the case of collisions of antiprotons and He atoms for the theoretical identification of the so called anti-cusp. In collisions of very low (2–11 keV) energy antiprotons with hydrogen molecule single ionization cross sections were determined for the first time in an experiment carried out in CERN. A surprising result was obtained, namely that the cross section increases proportionally with the velocity of the projectile.

At the Department of Physics of the University College London (London) the development of a measuring system suitable for the determination of the energy and angular distribution of the recoil target nucleus in positron-atom collisions was continued.

The charge transfer reactions $C^{2+} + HF \rightarrow C^{+} + HF^{+}$ and $H^{+} + CH \rightarrow H + CH^{+}$ were studied in the keV collision energy range. It was pointed out that the cross section of the processes strongly depends on the ion-molecule orientation. For the collision H^{+} + CH the calculations carried out at the Franck-Condon level were compared with more accurate calculations that

employ the sudden approximation for the rotation and vibration. The results of the FC and the sudden vibrational approximation do not show significant differences.
Negatively charged H^- fragments were identified in collisions of OH^+ +Ar and OH^+ + CH_3COCH_3 at few keV impact energies.
The ionization of the H atom and the water molecule was studied in a classical, linearly polarized laser field. For the solution of the problem classical (CTMC) and quantum mechanical (QM, strong field and Coulomb-Volkov) approximations were applied. The results were compared to the exact solutions of the time dependent Schrödinger equation.

Measurements were carried out in the visible light and X-ray ranges of the electromagnetic radiation emitted from the plasma of the electron cyclotron resonance (ECR) ion source. By the comparison of the photographs with each other and with computer simulations valuable information were obtained on the electron component of the plasma and on the ions trapping.

For investigating the connection of the living and glassy materials, the surfaces of insulators and metals were covered with low energy (50-100 eV) fullerene (C_{60}) ion beams followed by living cells growth on these surfaces (in collaboration with medical doctors).

The operation range of the ECR ion source was extended; from the year 2010 it can deliver high intensity negative H, O, OH and C^{60} ion beams.

The angular distribution of the Kr 4*p* photoelectrons was studied both experimentally and theoretically (in the independent particle model). The photo-ionization was investigated in the photon energy range of the $(3d)^{-1} \rightarrow np$ resonant excitations. From the difference between the measured and calculated photon energy dependence of dipole anisotropy parameters it was concluded that interference may occur between the direct ionization and the resonantly excited Auger decay process. It is the first experimental study where interference was observed between direct and indirect photoionization channels in electric quadruple (E2) interaction.
At the electron cyclotron resonance (ECR) ion source of Atomki the angular distribution of 3 keV Ar^{7+} ions transmitted through capillaries with diameter of 200 and 400 nm in polyethylene therephthalate (PET) foils was investigated as function of time. The time-dependence of the angular distribution of atoms created by neutralization of ions was also measured. This is the first detailed study for atoms. In accordance with earlier experiments, the ions were guided along the direction of the capillaries, and oscillations appeared in the angular distribution. For atoms, the oscillations were smaller and deviated in phase. From the observations, conclusions for the mechanisms of neutralization have been drawn.
Within an international collaboration at Zernike LEIF laboratory in The Netherlands, guiding of Ne^{7+} ions was investigated in capillaries in PET and polycarbonate foils with different diameters in the range of 100-400 nm. Large differences in the guiding properties were observed comparing the two materials. For polycarbonate, some time after the ion beam was switched on, almost complete blocking of the capillaries was observed.

For the first time, it was shown experimentally that capillaries of macroscopic diameter can transmit electrons of several hundred eV energy without a significant energy loss, even when the geometrical conditions otherwise would not allow.

Applications in Atomic Physics, Solid State Physics, Surface Studies
Multiwall carbon nanotubes (MWCNTs) supported Pd and Pd-Au alloy nanocatalyst surfaces (important for fuel cell applications) were studied using electron spectroscopic methods, following different (reducing and calcination) treatments. The results of the surface analysis shows that the differences in activity of the investigated Pd/MWCNTs catalysts after reduction and calcination result from the amorphous carbon covering the PdO/Pd nanoparticles, where the PdO layer is of larger thickness for inactive catalyst.

1s photoelectron spectra excited from 3d transition metals (Cr,Mn,Fe,Co,Ni) by synchrotron radiation were measured, and, on the basis of the analysis and ab initio theoretical modelling

of the spectral shapes, it was shown for the first time that the satellite structure indicating shake-up excitation is present in the 1s spectra of each transition metal investigated.

In the case of Al nanorods of cylindrical symmetry the mechanism of plasmon excitation by a suddenly created electron-hole pair was studied using the dielectric function approximation. The results show that the presence of the hole is relevant and leads to a significant contribution to the total probability of exciting surface plasmons and that the surface plasmon excitation by the electron and the hole cannot be considered as independent processes within the so called intrinsic-extrinsic or three step model.

The effect of multiple electron scattering on the spectra of electrons backscattered from solids was studied using extended Monte Carlo calculations. The calculations were performed for the case of bilayer samples and relativistic electron energies. It was shown that multiple electron scattering can influence both the shape and the width of the spectra.

The interaction of fast atoms and Al surface at glancing incidence was studied by Monte Carlo calculations. It was shown that a*b initio* atom-surface potentials based on density-functional theory are required to reach a satisfactory agreement with experiment.

Thin film layer structures were produced by physical sputtering, electrochemical and chemical vapour deposition (CVD) methods. These thin film layers were studied using secondary neutral mass spectrometry (SNMS). For concentration depth profile analysis measurements, the dependence of the depth resolution on the surface roughness was determined. It was experimentally proved that in the depth profile analysis performed using SNMS the main parameters which determine the depth resolution are the shape of the crater and the surface roughness. The concentration change of the composition elements of FeCoNi alloys were also determined, in the first few nm thickness of the deposited layer, due to preferential chemical deposition. Thermal diffusion processes in thin layers produced by CVD and sputtering were studied for solar cell studies.

A method based on the SNMS measurement technique for quantitative depth profiling of surface layers and thin films was elaborated. Using a low energy (100-300 eV) ion sputtering, from the measured depth profile, the surface roughness and the sputtered crater profile determined experimentally the true depth profile can be reconstructed within 1 nm accuracy.

Electronic transport properties of ferromagnetic-superconductive layers produced by electro-chemical deposition were investigated at low temperatures as a function of chemical composition. Although this phenomenon is well known, the related experimental studies in the case of films produced by electrochemical deposition are novel ones. The chemical composition and surface roughness analyses were made using SNMS.

In the field of hyperthermia-therapy, the efficiency of Neél-type energy dissipation process of a nanomagnetic particle was calculated. The results are to be checked experimentally.

Nanopowders were produced by high energy ball milling from Cu_6PS_5I superionic crystals - promising materials for nano- and optoionics. The powders with grain sizes of 20-100 nm were used to prepare ceramics and studying their physical properties. GSO and LSO scintillator crystals were also ball milled down to nanosize in order to investigate their scintillation mechanisms at different crystallite sizes.

In/SnO, Ni/Pd, Ag/Pd, Ni/Si and $As_{20}Se_{80}/AlSiO_5$ multilayer films produced by magnetron sputtering were studied using the XRD method. In the Ni/Si system the nanoscale evolution of interface upon annealing at elevated temperature was investigated using the SNMS technique. Various crystalline product phases were identified from the XRD results.

Phase analysis of various crystalline compounds by X-ray powder diffractometry, and XRF analysis of archaeological objects from the collections of Hungarian museums have been also performed.

Environmental Physics

Preparation of volcanic rocks started for K/Ar dating collected in the King George Island, Antarctica. The intrusive magmatism of the Carpathian-Pannonian Region (CPR) has been studied. A discovery of a new effect and the study its impact on the K-Ar age of leucite-bearing basaltic rocks was achieved. The chronology of Tertiary volcanic phases of the Bohemian Massif. Change of formal K-Ar age of clay minerals in soil was improved as an effect of vegetation and fertilization. Chronology of low-grade metamorphic rocks in Slavonia, Croatia was performed.

Atomki developed a novel CO_2 absorption method was introduced into the routine C-14 measurement methods. Hundreds of samples were measured using this new method. A new method was developed for ultra small (C<0.1mg/sample) carbonate and groundwater samples in cooperation with ETHZ (Zürich, Switzerland). The sealed tube graphitization method was optimized and adapted into the C-14 AMS laboratory of Atomki. Fossil CO_2 level in Debrecen city was measured during the year of 2009 and 2010.

An ultrapure ^{4}He method was developed in measurement of tritium concentration of environmental water samples by the ^{3}He-ingrowth method. Evaluation of stable isotope compositions were performed (δ^2H, δ^{18}O) of precipitation samples of 9 years, together with the determination of the local meteoric water line. Experimental investigation and modelling of tritium wash-out was done by precipitation from the tritium plume of the nuclear power plant of Paks, Hungary. The Atomki Paleoclimate study was based on noble gas temperatures and radiocarbon ages of groundwater samples from the southern Great Hungarian Plain. Method development to determine noble gas concentrations of fluid inclusions in speleothems was also performed.

From the analysis of their continuous radon measurements, Atomki researchers have determined the natural ventilation rates of wine cellars which is a basic parameter to determine the climate of these cellars. They have also found that in some cellars barometric pumping plays important role in shaping the climate of these cellars by pumping out gases from the embedding rock.

A new method was developed for trace gas analyses and leak test of the container wells used for the storage of spent nuclear fuel rods in the Hungarian repository (Paks) .

Water relations of different oak species and their hybrides (20 trees) have been studied in field experiments in the research area of the Síkfőkút Project of University of Debrecen. The measured time series of the relevant parameters cover the whole season. A multi-parameter analysis of the data can lead to a better understanding of the ecological responses of the Hungarian oak forests to climate changes.

Instruments and accelerators

In the frame of international cooperation the shot noise of silicon photomultipliers (SiPM,) provided by the producer at the institute's disposal, was investigated experimentally. The noise amplitude distribution has been modelled using analytical and numerical approaches as well. Methods for the electro-optical and nuclear characterization of SiPM photodetectors has been developed. These developments serve as feedback for the semiconductor company (STMicroelectronics, Italy) to improve device parameters

A simple and low power consumption new type of circuitry, eliminating the effect of the large capacitance of SiPMs, has been developed for position readout of SiPM 2D matrix.

A new digital timing method has been developed for signals with risetime shorter than the sampling interval. The method was tested for $LaBr_3$ scintillator using the digital signal processing card of Atomki. A further aim is the application of this solution in advanced detector systems for international nuclear physics experiments (GANIL/Spiral2, Caen). The optimal conditions to improve low energy p-α discrimination threshold of CsI(Tl) scintillators using silicon avalanche photodiode (SiAPD) readout has been established.

Improvements in the image reconstruction software of the Cardiotom mobile tomographic gamma camera were also performed. The iterative image reconstruction was extended with resolution recovery capability, which improves significantly the spatial resolution of the detector system, especially in the case of sources far from the camera head. A software was developed for position sensitive gamma detector which acquires 2D position maps and energy spectrum, image filtering in a predefined energy range, and energy spectrum determination in different regions of the picture. It also corrects the inhomogenities of the applied Hamamatsu position sensitive photomultiplier tube.
For electron spectroscopic purposes a six channel digitally controlled high precision, floating power supply with 10 ppm stability in the range of 0-10 kV has been developed. The small value of the low frequency noise component is assured by using accumulator powering.
The upgrade project of the PHENIX (RHIC, BNL) contained development of both new hardware and software. A multichannel FPGA based TDC and generic UDP/IP transport module supporting high speed data transfer were developed for different type of detectors.
The 20 MeV cyclotron supplied proton, deuterium and alpha beams for the nuclear astrophysics and spectroscopy, isotope production, thin layer activation, radiation tolerance tests. Several improvements have been applied for the control system of the accelerator.

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b) Relationship between science and society

As it can be expected the research results in Atomki have direct impact on society. Based on our nuclear physics studies we were able to refine the parameters of reactor decay heat. With the extension of our aerosol studies to schools, workplaces, we provide valuable information on the environmental and health impact of urban aerosol for the society. Our industrial projects have direct relevance on energy saving, environment protection. Through the medical and pharmaceutical programs we address important health issues
The Physicists' Days of Atomki have been organized for the 31st time in 2010. This event draws the attention not only from the city of Debrecen, but also from the neighbouring regions. More than 1000 pupils visited Atomki during the recent Physicists' Days with its main theme: 'Physicists and Physicians'. As side events to the talks different medical diagnostic instruments have been on display.
The highlight of Researchers' Night in 2010 was the premiére of the new Atomki edutainment movie entitled 'Lab Love'. The screening was so successful, that had to be repeated due to the unexpectedly high number (350) of viewers. The film was aired later by a major national TV channel M1 in November with an additional promotion interview.
Atomki as a traditional supporter of nuclear energy organized two outreach events on the subject in 2010:
Organized in Atomki, 180 visitors attended the event entitled 'Towards the extension of the Hungarian nuclear power plant'. The Atomki researchers presented their related work in a poster session. Atomki co-organised the event 'Nuclear Energy for Everybody' with 341 registered participants mostly from high schools. This event was accompanied by an exhibition of nuclear related instruments, detectors, developed in Atomki.
The most prominent science TV-show in Hungary (DELTA) reported twice on Atomki laboratories in 2010. Apart from our natural target, the science journals, a wide range of general journals published thoughts and views of Atomki researchers, and all major popular science journals had contributions from Atomki scientists.
Atomki supports the young generation to contribute to the work of the Young Scientists' Network for Nuclear Science in Hungary. In 2010 'nuclear-tents' have been built up at several

summer festivals, and youngsters also from Atomki distributed leaflets and questionnaires on nuclear energy, environment awareness, climate issues to the interested public also in English. From the 15 types of questionnaires 2100 was filled in spreading the science issues among the young generation.

III. A presentation of national and international relations

There are intensive co-operations in a wide range of topics with many institutions both in Hungary and abroad. The stability and permanent renewal is characteristic for the situation; In 2010 new or extended cooperation agreements were signed between Atomki and the Institute of Electron Physics of the Ukrainian Academy of Sciences in Uzhgorod similarly with RIKEN Nishina Center for Accelator-Based Science and also with Forschungszentrum Dresden – Rossendorf. A collaboration frame agreement was signed between the Royal Institute of Technology, the Adolesco AB, the Debrecen University and two institutes of it and Atomki. In the field of education a cooperation agreement was made with the Budapest University of Technology and Economics. An agreement was signed also with the Department of Radiation Therapy of the University of Debrecen.

Our institute maintains a net of widespread domestic cooperation on each research-field of our scientific activity. Most of these co-operations have started years or decades ago, therefore ensuring the integration of our basic and applied physics research activities. Especially important our collaboration with the following institutes: HAS RMKI, Departments of Experimental Physics, Theoretical Physics, Botany, of the University of Debrecen (DU), HAS AEKI, Institute of Nuclear Techniques of Budapest University of Technology, University of Szeged, Institute of Nuclear Medicine UD, Department of Physics of the University of Miskolc, Department of Radiochemistry of the University of Veszprém, HAS MFA, HAS Institute of Archeology, Budapest History Museum, National Museum of Hungary.

The most important domestic research projects started or renewed in the reporting period were:

- in the field of atomic physics and its applications: Department of Experimental Physics of Budapest University of Technology, HAS RMKI, HAS MFA, ISOTOPTECH CC.
- in the field of physics of condensed structures: HAS SZFKI, Department of Radio Chemistry of the University of Veszprém, Eötvös Loránd University, Laboratory of Nuclear Chemistry, TKI-Ferrite Manufacturing and Development Ltd., HAS Chemical Research Center, Kraft Projekt, University of Szeged, Paks Nuclear Power Plant CC.
- in the field of ion beam analysis: HAS Air-chemistry Group of the Pannon University, Department of Archeology of the University of Szeged, National Institute of Environmental Sanitation Studies, National Meteorological Service, UD Clinic of Dermatology.
- in the field of environmental research and dating: Eötvös Loránd University, RHKT PBO of Püspökszilágyi, MECSEKÉRC Environmental Protection CC., MecsekÖKO Environmental Protection CC., Fácies Lp., Envicom 2000 Ltd., Hydrosys Ltd., Smaragd GSH Ltd., Enviroinvest Ltd., VIZITERV Environ Ltd. Nyíregyháza, Institute of Nuclear Techniques of the Budapest University of Technology, National Meteorological Service, Scopia Lp., AktAnal Lp., RadAnal Lp.
- The Pharmatom Hungaria Ltd. (a project company of the Pharmapolis Innovative Cluster) was established by Richter Gedeon Inc., UD, HUNIKO Ltd., Experimetria

Ltd., Pharmapolis Ltd. The project company focuses on the development of new PET tracers for application in early clinical trials of new pharmaceuticals.

- The ICONO-Pharma Ltd. was established by the same members of Pharmapolis Innovative Cluster in order to provide a nourishing R+D+I environment for the innovative pharmaceutical research companies and producers.
- Atomki is also involved in the activities of the Space Research Cluster and the Thermal and Healthcare Cluster; and has also founded a further cluster (the Prizmatech Cluster) with 6 additional members, which focuses on the institute's interest areas: health industry, mechatronics and environmental science.

Participation in higher education

Our institute continued to play an important role in the graduate and undergraduate education in 2010, and nourished the traditionally good relationship with the University of Debrecen (UD). The researchers of Atomki announced 64 courses and gave 1033 curricular lectures in the reporting period, contributing to the educational work of the UD. The number of practical lectures held by our researchers at the UD was 509 in 18 announced courses. 35 researchers participated in the education. The institute was involved in the training of undergraduate students in the following majors: physicist, physics teacher, informatics specialist, software designer mathematician, environmental science, basic environmental science, and agricultural environmental management engineer. 14 PhD students, 11 MSc students and 3 members of the Scientific Students' Associations worked in the institute during the reporting period; the number of hours spent on advisory work was 1948.

Following the tradition of the previous years our institute announced in 2010 – in cooperation with the Physics Institute and Informatics Faculty of UD – the *Nuclear Imaging* course. The purpose of the course was to give a summary of the various imaging methods playing an important role in the practical application of nuclear physics. A new development related to this course is an agreement signed with the Budapest University of Technology and Economics (BME) and with the Babes-Boyai University at Cluj-Napoca. The institute participated in the education of students with medical engineering and medical physics major from the partner universities by providing the curriculum and the location for the practical courses. The institute has also organized the Medical Physics section of the 2010 Balaton Summer School (held at Balatongyörök from July 11 to 18, 2010).

The Environmental Physics Department of the UD is located in Atomki. This department participates in the education of students in physics, environmental studies and environmental sciences.

IV. Brief summary of national and international research proposals, awarded in 2010

The Atomki obtained major international supports from the following organizations: AC^2T Research GmbH Austria, Foundation of Telecommunication and Telematics, EGT Norwegian Finance Mechanism – NFSR, ENIAC Call 2009, EU, IAVF, UT Battelle LLC (USA). The main Hungarian supports came from National Development Agency, National Foundation for Research and Technology, NFSR, Paks Nuclear Power Plant CC.
The institute had 95 projects in 2010. Below we list those 38 projects for which the full budget was higher than 10 million HUF. We indicate the sum that goes to Atomki and the part for the year 2010. The project duration goes from 1 to 5 years, most frequently 3 – 5 years.

AC^2T Research GmbH Austria: TLA wear measurement, 25440 EUR - 15540 EUR ||
Foundation of Telecommunication and Telematics: Microwave based R&D activity,

30000 kHUF – 30000kHUF ||
Norwegian Finance Mechanism – NFSR: Aerosol analysis for East Hungarian, 14551 kHUF – 3929 kHUF ||
ENIAC Call 2009: Central Nervous System Imaging, 50100 EUR – 13917 EUR ||
NKTH: Central Nervous System Imaging, 67976 kHUF ||
European Union: Development of CVD based detectors for radiotherapy, 34242 EUR – 10040 EUR || Development of E+ E- detectors, 79500 EUR || EURATOM Fusion Training, 149227 EUR || The laboratory of future in materials science and engeniering, 95444 EUR – 23861 EUR || TRI-TOFFY, 65000 EUR - 24000 EUR || Surface wear measurement, 82267 EUR – 5000 EUR || Collective excitation in atomic ionization, in semiconductors and in biological tissues, 100000 EUR – 25000 EUR || Study of nuclear reactions important for astrophysical p-process, 750000 EUR – 159024 EUR || CHARISMA-project 197000 EUR – 35040 EUR || Development of detectors and electronics for gamma spectroscopy, 12000 EUR – 2427 EUR ||
IAVF: Wear measurement, 45793 EUR – 8100 EUR ||
UT Battelle LLC (USA): Sample preparation, 37880 USD – 37880 USD ||
NFÜ: Decreasing of heatloss of buildings, 71816 kHUF - 71816 kHUF || Complex development of building energetics, 342208 kHUF – 119208 kHUF || North- Plain PRIZMATECH Instrumentation and Development Cluster Management, Debrecen, 30764 eFt ||
NKTH- OTKA: Nuclear physics methods for creation of elements, 18000 kHUF – 9000 kHUF || Study of higher order effects at atoms, 10000 kHUF – 5022kHUF ||Search for new physics at CERN CMS detector, 29359 kHUF – 14539 kHUF || Development of gas ionsource and preparation methods for environmental samples || 18747 kHUF || Study of astrophysics of 3He + 4He reaction, 24000 kHUF – 12000 kHUF || LHC Grid Center, Debrecen, 65300 kHUF – 65300 kHUF ||
NKTH: Measurement of chemical states of components for surface layers, 71250 kHUF – 71250 kHUF || New generation thin layer solar cells, 40000 kHUF – 10000 kHUF || Multimodality imaging system, 82112 kHUF ||
OTKA: Symmetries in the quantummechanical many-body problems, 11000 kHUF – 2800kHUF || Study of basic interactions and exotic nuclear states with lasers and particles, 23157 kHUF – 6407 kHUF || The role of intrusive bodies in the Carpaty, 10660 kHUF – 2787 kHUF || Influence of atomic environment on resonant and non resonant processes, 16000 kHUF – 4000 kHUF || Atomic processes important for the radiation hardness, 12460 kHUF – 2770 kHUF || Nucleosynthesis of heavy elements, 21998 kHUF – 6940 kHUFeFt ||
Paks Nuclear Power Plant CC: Measurement of rare isotopes in liquid radioactive waste, 44932 kHUF – 22798 kHUF ||
RHKT PBO of Püspökszilágyi: Measurement of environmental samples, 108788 kHUF – 25990 kHUF ||

V. List of important publications in 2010

Algora A, Jordán D, Taín JL, Rubio B, Agramunt J, Perez-Cerdan AB, et al. (42), Krasznahorkay A, Hunyadi M, Gulyás J, Vitéz AC, Csatlós M, Csige L, Reactor decay heat in 239Pu: Solving the gamma discrepancy in the 4-3000-s cooling period, ***PHYSICAL REVIEW LETTERS (ISSN: 0031-9007)*** **105**: *Paper 202501(4).* (2010), IF: 7.328

Elekes Z, Vajta Zs, Dombrádi Zs, Aiba T, Aoi N, Baba H, et al. (23), Fülöp Zs, Kiss Á, , Sohler D, Nuclear structure study of 19,21N nuclei by gamma spectroscopy, ***PHYSICAL REVIEW C*** **82:**(2) *pp. 7305--4.* (2010), IF: 3.477*

Force C, Grévy S, Gaudefroy L, Sorlin O, Caceres L, Rotaru F, et al. (24), Dombrádi Z, Sohler D, Prolate-spherical shape coexistence at N=28 in 44S, ***PHYSICAL REVIEW LETTERS (ISSN: 0031-9007)*** **105**: *Paper 102501(4).* (2010), IF: 7.328*

Gyürky Gy, Elekes Z, Farkas J, Fülöp Z, Halász Z, Kiss GG, et al. (12), Somorjai E, Szücs T, Alpha-induced reaction cross section measurements on 151Eu for the astrophysical gamma-process, ***JOURNAL OF PHYSICS G (ISSN: 0954-3899)*** **37**: *Paper 115201(15).* (2010), IF: 2.124*

Huszánk R, Szilasi S Z, Rajta I, Csik A, Fabrication of optical devices in poly(dimethyl-siloxane) by proton microbeam, ***OPTICS COMMUNICATIONS*** **283:** *pp. 176-180.* (2010)

Itagaki N , Cseh J, Ploszajczak M, Simplified modelling of cluster-shell competition in 20Ne and 24Mg, ***PHYSICAL REVIEW C 83(ISSN: 0556-2813)***: *Paper 014302(12).* (2010), IF: 3.477*

Juhász Z, Sulik B, Rácz R, Biri S, Bereczky RJ, Tőkési K, et al. (9), Kövér Á, Pálinkás J, Stolterfoht N, Ion guiding accompanied by formation of neutrals in polyethylene terephthalate polymer nanaocapillaries: Further insight into a self-organizing process, ***PHYSICAL REVIEW A (ISSN: 1050-2947)*** **82**: *Paper 062903(7).* (2010), IF: 2.866*

Knudsen H, Torii HA, Charlton M, Enomoto Y, Georgescu I, Hunniford CA, et al. (15), Tőkési K, Target structure induced suppression of the ionization cross section for very low energy antiproton-hydrogen collisions, ***PHYSICAL REVIEW LETTERS (ISSN: 0031-9007)*** **105**: *Paper 213201(4).* (2010), IF: 7.328*

Lévai G, Arias JM, Search for critical-point nuclei in terms of the sextic oscillator, ***PHYSICAL REVIEW C81 (ISSN: 0556-2813)***: *Paper 044304(11).* (2010), IF: 3.477*

Mohr P, Galavíz D, Fülöp Z, Gyürky G, Kiss GG, Somorjai E, Total reaction cross sections from elastic alpha-nucleus scattering angular distributions around the Coulomb barrier, ***PHYSICAL REVIEW C82 (ISSN: 0556-2813)***: *Paper 047601(3).* (2010), IF: 3.477*

Molnár M, Haszpra L, Svingor É, Major I, Svetlik I, Atmospheric fossil fuel CO2 measurement using a field unit in a CentralEuropean city during the winter of 2008/09 ***RADIOCARBON (ISSN: 0033-8222)*** **52**: (2-3) *pp. 835-845.* (2010), IF: 1.257*

Nándori I, Nagy S, Sailer K, Trombettoni A, Phase structure and compactness, ***JOURNAL OF HIGH ENERGY PHYSICS (ISSN: 1126-6708)*** 2010: *Paper 090069(25).* (2010),

Pál KF, Vértesi T, Maximal violation of a bipartite three-setting, two-outcome Bell inequality using infinite-dimensional quantum systems, ***PHYSICAL REVIEW A*** **82:** *p. 022116.* (2010) IF: 2.866*

Palcsu L, Major Z, Köllő Z, Papp L, Using an ultrapure 4He spike in tritium measurements of environmental water samples by the 3He-ingrowth method, ***RAPID COMMUNICATIONS IN MASS SPECTROMETRY (ISSN: 0951-4198)*** **24**: *pp. 698-704.* (2010), IF: 2.695*

Peter L, Csik A, Vad K, Toth-Kadar E, Pekker A, Molnar G, On the composition depth profile of electrodeposited Fe-Co-Ni alloys, ***ELECTROCHIMICA ACTA*** **55:**(16) *pp. 4734-4741.* (2010), IF: 3.325*

Rácz R, Biri S, Pálinkás J, Electron cyclotron resonance plasma photos, ***REVIEW OF SCIENTIFIC INSTRUMENTS (ISSN: 0034-6748)*** **81**: *Paper 020708(3).* (2010), IF: 1.521*

Rajta I, Gál G A B, Szilasi S Z, Juhász Z, Biri S, Mátéfi-Tempfli M, Mátéfi-Tempfli S, Nanochannel alignment analysis by scanning transmission ion microscopy, ***NANOTECHNOLOGY*** **21:**(29) *p. 295704. Paper 295704.* (2010), IF:3.137*

Ricz S, Ricsóka T, Holse K, Borovik AJ, Bernhardt D, Schippers S, et al. (9), Kövér Á, Varga D, Interference effect in the dipole and nondipole anisotropy parameters of the Kr 4p photoelectrons in the vicinity of the Kr(3d)-1 -> np resonant excitations, ***PHYSICAL REVIEW A (ISSN: 1050-2947)*** **81**: *Paper 043416(7).* (2010), IF: 2.866*

Sarkadi L, Classical trajectory Monte Carlo model calculations for ionization of atomic hydrogen by 75-keV proton impact, ***PHYSICAL REVIEW A (ISSN: 1050-2947)*** **82**: *Paper 052710(11).* (2010), IF: 2.866*

Stobinski L, Lesiak B, Kövér L, Tóth J, Biniak S, Trykowski G, Judek J, Multiwall carbon nanotubes purification and oxidation by nitric acid studied by the FTIR and electron spectroscopy methods, ***JOURNAL OF ALLOYS AND COMPOUNDS (ISSN: 0925-8388)*** **501**: *pp. 77-85.* (2010), IF: 2.135*

Stolterfoht N, Hellhammer R, Juhász Z, Sulik B, Bodewits E, Dang HM, Hoekstra R Guided transmission of 3-keV Ne7+ ions through nanocapillaries in insulating polymers: Dependence on teh capillary diameter, ***PHYSICAL REVIEW A (ISSN: 1050-2947)*** **82**: *Paper 052902(8).* (2010), IF: 2.866*

Tárkányi F, Ditrói F, Király B, Takács S, Hermanne A, Yamazaki H, et al. (9), Study of activation cross sections of proton induced reactions on barium: Production of 131Ba -> 131Cs, ***APPLIED RADIATION AND ISOTOPES (ISSN: 0969-8043)*** **68**: *pp. 1869-1877.* (2010), IF: 1.094*

Vértesi T, Pironio S, Brunner N, Closing the detection loophole in Bell experiments. ***PHYSICAL REVIEW LETTERS*** **104:** *p. 060401.* (2010), IF: 7.328*

Wang ZM, Chapman R, Liang X, Haas F, Bouhelal M, Azaiez F, et al. (39), Dombrádi Z *Intruder negative-party states of neutron-rich 33Si,* ***PHYSICAL REVIEW C (ISSN: 0556-2813)*** 81: *Paper 064301(7).* (2010),IF:3.477*

Wilson AN, Korichi A, Siem S, Astier A, Bazzacco D, Bednarczyk P, et al. (26), Nyakó BM, Timár J, Two-particle separation energy trends in the superdeformed well, ***PHYSICAL REVIEW LETTERS (ISSN: 0031-9007)*** **104**: *Paper 162501(4).* (2010), IF: 7.328*