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I. Main duties of the research unit in 2011

The main tasks of Atomki, 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 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 2011

a) Outstanding research

Quantum Physics

Optimal device-independent witnesses of genuine multipartite entanglement have been generated for the noisy 3-qubit Greenberger-Horne-Zeilinger (GHZ) state for visibilities as low as 2/3 using an arbitrary number of settings. This method is independent of the chosen tool and optimal in the sense that the value of noise tolerance cannot be reduced below 2/3 even for infinite number of measurements.

Two two-qubit states have been found such that any number of copies of one state or the other cannot violate the Clauser-Horne-Shimony-Holt (CHSH) Bell inequality, which holds for classical correlations. However, their tensor product can produce a CHSH violation. They also identified a CHSH-local state such that two copies of it are CHSH-violating. Furthermore CHSH violation can be easily generalized for more than two-qubit states.

Transitions between different phases of nuclei were considered. The main question here is the number and type of phase transitions (first- or second-order phase transition). Investigations have been started on the semimicroscopic algebraic cluster model (SACM) that describes nuclear clusterization. A special phenomenological limit (PACM) of the model was defined, in which the Pauli principle was ignored. First- and second-order phase transitions have been identified, while in the case of the SACM a critical line has also been found. The ^{16}O+alpha and ^{20}Ne+alpha systems were explored and it was found that the energy spectrum derived from the PACM differs considerably from the observed one.

The most general exactly solvable non-relativistic potential problem is represented by the six-parameter Natanzon class. Solutions have been given before for special cases only, for example shape-invariant potentials. In order to fill this gap, a four-parameter subset of the Natanzon class was considered that is solved by Jacobi polynomials and contains all six shape-invariant potentials of this type. It was shown that these six potentials can be transformed into each other pairwise in three disjoint regions of the parameter space.

The trajectories of S-matrix (scattering matrix) poles are calculated in the finite-range phenomenological potential introduced recently by Salamon and Vertse (SV). The potential is similar to a Woods-Saxon (WS) interaction, but it is exactly zero beyond a radius, without

any cutoff. The strong dependence of the resonance trajectories on the cutoff radius is demonstrated.

Within the complex-energy configuration-interaction framework, correlations of valence neutrons were studied to explain the behavior of charge radii in neutron halo nuclei ^{6,8}He. It was found that the experimentally observed decrease of the charge radius between ^{6}He and ^{8}He is caused by a subtle interplay between three effects: dineutron correlations, a spin-orbit contribution to the charge radius, and a core swelling effect. It was demonstrated that two-neutron angular correlations in the 2_1^+ resonance of ^{6}He differ remarkably from the ground-state correlations in ^{6,8}He.

In case of the ^{56}Ni nucleus the superdeformed state has been observed experimentally. The authors applied a shell-model description for this state, and from the same calculation they determined other possible shape isomers of this nucleus. In this way a theoretical prediction is given for the hyperdeformed shape, and also for even more elongated states. The possible binary clusterizations of these special states have also been investigated systematically, and the results give a hint for the reaction channels in which it can be populated.

The unbound quasiparticle energy spectrum of the Hartree-Fock-Bogoliubov (HFB) equations was examined. The structure of the unbound quasiparticle spectrum of weakly bound nuclei was studied within several methods that do not rely on imposing scattering or outgoing boundary conditions. It is shown that the stabilization method works well for all HFB resonances except for very narrow ones.

Particle Physics

The Large Hadron Collider (LHC) at CERN worked far above expectations in 2011. It reached a new milestone in its main goal, the discovery of the Higgs boson: its allowed mass has been severely restricted by the two large general-purpose experiments, ATLAS and CMS to the interval between 115 and 130 GeV. The heavy ion programme of CMS accomplished much as well. The positioning system of the barrel muon detector, that part of the CMS system which was built and is operated by the Atomki group worked very well all throughout the first two years of LHC running. Atomki physicists wrote a detailed work book of the safety control of CMS, and they have a predominant role in operating the CMS detector control system. They participated in running and calibrating the heart of CMS, the pixel detector, which has a key role in determining particle trajectories and an Atomki physicist became the leader of the CMS pixel group.

They continued their project on the theory of NNLO computations. In particular, they integrated two of the four different types of doubly-unresolved subtraction terms over the factorized phase space of the two unresolved partons. They also worked on finding a fast numerical implementation of sufficiently precise approximation of these complicated integrals.

They worked out the combination of two public programs in order to generate unweighted Monte Carlo events at the parton level, which then can be interfaced with parton shower Monte Carlo (SMC) programs. Using this method, they obtained predictions for the hadron level cross section of $tt^- + X$ hadroproduction, where X means a hard object within the Standard Model (SM) (jet, Higgs particle, Z particle) and within the Minimal Supersymmetric SM (pseudoscalar Higgs).

The interplay of bosonization and renormalization group has been investigated. The Low-energy scaling of the 2-dimensional quantum chromodynamics was determined. Based on

bosonization, a new method has been developed to optimize the renormalization scheme-dependence.

Nuclear Physics

The magic numbers, having paramount importance to understand the nuclear structure, are changing in the case of a significant shift in the proton to neutron ratio. In light (N, Z <20) nuclei this shift can be understood as a consequence of the proton-neutron monopole interaction, which results in a gradual change of the single particle energies as a function of the proton (neutron) number. In connection with the study of the structure of ^{39,41}Si nuclei from fragmentation of a radioactive beam cocktail at Ganil, it has been shown that in heavier nuclei, where the shell closures cannot be assigned to oscillator shell closures, the proton-neutron quadrupole correlation proportional to the number of the protons and neutrons is able to deform the nucleus even if the shell gaps are relatively large.

The second edition of Handbook for Nuclear Chemistry was published in 2011 in a revised six-volume form, with many articles written by colleagues of Atomki. The first volume dealing mainly with nuclear physics was edited by one of Atomki researchers.

The fission probability of ^{232}U has been measured using the ^{231}Pa(^{3}He,df) reaction with an energy resolution of 11 keV. Below E* = 4.8 MeV they found rotational bands with a rotational parameter characteristic to a hyperdeformed nuclear shape. Around 5MeV it was proved to have a rotational structure with a rotational parameter characteristic to a superdeformed-like nuclear configuration.

The OBELISK 4π detector system based on PPAC detectors has been made suitable to investigate charged particle induced fissions.

Results of the analysis of the measurement of the beta decay of some refractory isotopes that were considered as possible important contributors to the decay heat in reactors have been presented.

Prototypes of the Low Energy Neutron detector Array (LENA) have been tested in Los Alamos, US and compared with detailed GEANT simulations. The simulations agreed very well with the measured response. For the first time the LENA was used to detect low-energy neutrons from (p,n)-type reactions with low momentum transfer at the R3B and EXL setups at FAIR, Darmstadt.

High resolution experimental data have been obtained at RCNP, Osaka for the ^{40,42,44,48}Ca(^{3}He,t)Sc charge exchange reaction at 420 MeV beam energy, which favors the spin-isospin excitations. The measured angular distributions were analyzed for each state separately, and the relative spin dipole strength has been extracted for the first time. The low-lying spin-dipole strength distribution in ^{40}Sc shows some interesting periodic gross feature. It resembles to a soft, dumped multiphonon vibrational band with $\hbar\omega$ = 1.8 MeV, which might be associated to pairing vibrations around ^{40}Ca.

Excited states of ^{92}Pd have been studied using the ^{58}Ni(^{36}Ar,2*n*)^{92}Pd fusion–evaporation reaction in order to investigate the proton-neutron interaction. In nuclei with equal neutron and proton numbers ($N = Z$), enhanced correlations arise between neutrons and protons that occupy orbitals with the same quantum numbers. Such correlations have been predicted to favour an unusual type of nuclear superfluidity, termed isoscalar neutron–proton pairing. The obtained properties of the experimental excited states have been compared with results of shell-modell calculations. The comparison shows that the anticipated new type isoscalar neutron–proton pairing exists in ^{92}Pd and plays an important role in forming the properties of the excited states.

Medium- and high-spin states of the chiral-candidate ^{134}Pr nucleus were studied using the ^{116}Cd (^{23}Na,5*n*) reaction. Unambiguous spin-parity assignments for the excited states could be performed. Several new bands have been found in this nucleus. One of the new bands may be a chiral partner band, which raises the question of rethinking the chiral nature of ^{134}Pr nucleus.

Medium- and high-spin states of ^{155}Gd have been studied using the ^{154}Sm(a,3n) reaction. It has been shown that the coupling of the [505]1/2 single-particle quasi-neutron orbital to the band based on the first excited 0^+ state of ^{154}Gd is blocked, while this orbital is coupled to the gamma-vibrational band. This finding confirms the concept that the first excited 0^+ states in $N = 90$ nuclei are not a beta-vibration but a second vacuum state.

The high spin states of ^{79}Kr were studied via the ^{70}Zn(^{13}C,4n) reaction to search for chiral doublet bands based on the three-quasi-particle configuration, $\pi g_{9/2}^{2} \otimes \nu g_{9/2}^{-1}$. A side band structure to the yrast band has been identified which may correspond to the anticipated chiral partner band based on the experimental signs and parities of the observed states.

It has been demonstrated that the activation method based on the detection of characteristic X-ray emission can be used to measure the cross section of some α-induced reactions of astrophysical relevance. The method has been used for studying the ^{169}Tm(α,γ)^{173}Lu and it has been found that theoretical calculations strongly overestimate the measured cross sections.

Through the precision experimental study of elastic α-scattering on ^{110}Cd and ^{116}Cd, it has been demonstrated that global optical potentials are not able to describe well the scattering cross section and its variation along isotopic and isotonic chains.

A new, increased precision value has been determined for the low energy extrapolated S-factor of the ^{14}N(p,γ)^{15}O reaction which is important in CNO cycle hydrogen burning. The cross section of ^{15}N(p,γ)^{16}O has been measured in a low energy range never reached before and a modified, more precise reaction rate has been recommended.

The cross sections for the ^{2}H(d,p)^{3}H and ^{2}H(d,n)^{3}He reactions, which is important in astrophysics, have been measured for the first time via the indirect Trojan Horse Method from 1.5 MeV down to 2 keV.

Resonance states in ^{27}P have been studied in a collaboration with RIKEN, Japan to determine experimentally the stellar reaction rate of ^{26}Si(p, γ)^{27}P.

The critical evaluation of the new experimental nuclear-structure data on all the A=128 and 129 nuclids has been completed. All data have been prepared for publishing.

Applied Nuclear Physics

Ion beam induced compaction, chemical and refractive index change were determined in poly-dimethylsiloxane (PDMS), then using this information, convex microlens array was produced by protonbeam writing.

In 2011, 7 measurement campaigns were carried out within the CHARISMA EU FP7 project; altogether 10 foreign researchers were hosted from Belgium, Bulgaria, Germany, Greece and Romania. Neolithic incrusted ceramics, pyramid material, antique pottery, Byzantine gold-leaf glass tesserae, findings from graves in Carpathian Basin, ornamental objects from the Middle Ages and metallic threads from textiles were analysed.

The measurement setup at the scanning nuclear microprobe, consisting of two Si(Li) detectors for PIXE (C-Ca/Ca-U), has been complemented with a HP(Ge) and a NaI(Tl) gamma

detectors, as well as with an upgraded, highly sensitive beam chopper. Applying PIGE, the detection limit for fluorine has been reduced to ~0.01%.

In collaboration with South-Africa, we proved that the beta-emitters have an effect similar to recoil effect for nucleus, if their decay is followed by Auger electron cascade, using the generator systems like ^{166}Ho/^{166}Dy and ^{90}Sr/^{90}Y. We suggested a new method to determine the chemical bond by the experimental data for this type of beta-emitters. It can be highly important in the nuclear medicine for targeted radionuclidic therapy.

The influence of iron and chromium were studied on cerium dioxide support during catalytic methanol conversion by novel radioisotope method. The consecutive coverage of the catalyst surface with ^{11}C- and/or ^{12}C-methanol gives information about weak and strong catalytic active sites. The traditional gas chromatograph analysis system was completed with a radiodetector.

The study of the activation cross sections and production yields of charged particle induced reactions for application of nuclear technology has been continued. New deuteron irradiation were done at the Cyclone90 cyclotron in Belgium up to 50 MeV on the targets Mg, Nd, Yb, Cr, Tb, Dy, Si, Eu, Pb, Sb, Tb, C, Sc and Gd.

Further investigations have been carried out to study the applicability of a home-made Epithermal Neutron Analyzer (ETNA) for routine detection of the presence of plastic explosives in airline baggage, air cargo and cargo containers. An overview has been compiled and published on the neutron methods developed by the Debrecen group for detecting explosives and illicit drugs in bulk materials.

Polycrystalline CVD diamond based devices have been irradiated with fast neutrons for the RadiCal EU FP7 project. The neutron induced radiation damage effects were studied in cooperation with international partners of the collaboration. The aim of the project is to develop radiation hard on-line dosimeter matrices mainly for radiotherapy purposes.

Together with the Austrian AC^{2}T institute, they have elaborated the application of new isotopes for the investigation of parts containing common basic materials as Fe, Cu. In several cases they performed real wear measurements by using the developed new methods.

A database has been constructed in the frame of the IAEA coordinated FENDL-3 project for activation cross section of proton and deuteron induced nuclear reactions on construction material for construction and radiation safety of high intensity accelerators and target systems.

Productions of ^{201}Tl, ^{123}I, ^{167}Tm, ^{99}Mo(^{99m}Tc), ^{113}Sn/^{113}mIn, ^{177g}Lu ,^{76,77}Br, ^{88,89}Zr medical related radioisotopes were examined, with special attention to contaminant radioisotopes.

In the framework of the PHARMATOM project the renovation of the radiochemical laboratory has been finished. Two hot cells were built and two automatic devices were purchased for ^{18}F and ^{11}C syntheses. The synthesis of labeled radiopharmaceuticals and their optimizations is in progress.

Atomic collision processes

They studied the angular distributions of the scattered projectiles in collisions of H and He atoms with energetic bare ions within the framework of the Born and the continuum distorted wave approximation. Their work was focused on the characteristic critical scattering angles. Only a single critical deflection angle was observed when one-electron transitions were considered, which is at variance with the recent experimental finding of additional peaks.

Multiple scattering theories predict more than one projectile critical deflection angle only when two or more electrons participate in the processes.

They performed measurements for the collision H^0 + He at the 1.5 MV Van de Graaff accelerator of Atomki. These investigations were motivated by the total scattering cross section measurements of the group in University College London. For the scattering of positronium (Ps) on atoms and molecules the London group has found that the Ps total cross sections were unexpectedly close to those of an electron moving at the same velocity. The comparison of the two projectiles (H^0 and Ps) is interesting because they both are neutral, the only difference is in their masses.

The charge transfer process in collisions of C^{2+} ions with hydrogen chloride was studied theoretically in the keV collision energy range. It was pointed out that a simple mechanism driven by the non-adiabatic radial coupling interaction between the entry channel and the highest charge transfer channel is exhibited for this collision system, and the total cross section exhibits a maximum for collision energy at 3 keV. This mechanism is completely different from the behaviour of the system with fluorid. In that case a two-avoided-crossing process was observed which was leading to an increase of the total cross section with collision energy. This shows that the charge transfer mechanism is basically dependent of the specific non-adiabatic interactions involved in each collision system.

Degeneracies in slightly bent tetra-atomic Renner-Teller-type molecular ions (e.g. acetylene cation) were examined. Using the second order perturbation theory for degenerate states involving excited states it was shown, that for slight distortions from the molecular linearity the Renner-Teller type degeneracy disappears and two conical intersections occur in such manner that for their positions a reciprocity relationship hold.

They have found a model for the mechanism of the observed hydrogen anion production in OH^+ + Ar and OH^+ + CH_3COCH_3 collisions. It has been shown that H^- production gets likely if both collision partners contain multi-electron atomic centers.

Fragmentation of water and methane molecules has been first measured by medium (65 keV/u) N^+ impact. They found that the dominant fragmentation channels are connected to multiple ionization events. The measurements have been performed at the newly developed VdG-5 beamline.

Plasma diagnostics measurements were carried out at the electron cyclotron resonance (ECR) ion source. By the comparison of the visible light and X-ray photos with each other and with computer simulations valuable information were obtained on the electron component of the plasma and on the trapping of the ions.

After exchanging the NdFeB radial magnet trap and strengthening the axial magnetic field, iron plasma was made in the ECR source and highly charged iron ions were implanted into pre-prepared fullerene (C_{60}) layers. The presence of the iron atoms at the calculated depth inside the C_{60} layer was successfully verified by the Atomki-SNMS device. This was the first step towards the production of a new fullerene material where the iron ion or atom is inside the carbon cage.

In atomic and molecular physics experiments molecular ion and negative ion beams play an increasingly important role. Negative ions of H^-, O^-, OH^-, O_2^-, C^-, C_{60}^- (with μA intensity) and positively charged ions beams of H^{2+}, H^{3+}, OH^+, H^{2+}, H^{3+}, O^{2+} (in the mA range) were generated by the ECR ion source. The Atomki-ECRIS proved again that various requirements for plasma physics investigations, for low energy atomic physics measurements and for applications can be fulfilled by one multi-purpose ECR ion source.

The angular distribution of the Kr 4p photoelectrons was studied experimentally in the *3d* resonant excitations of electrons. From the measured spectra the left-right asymmetry parameters (ALR) were determined as a function of the photon energy. They found that the values of ALR were sensitive to the interaction between the ionization and excitation channels. An interesting result is that the sign of the asymmetry parameter changed from positive to negative and then back again to positive just within a narrow photon energy range of only 250 meV around the $3d_{5/2} \rightarrow 5p$ resonant excitation energy for both spin-orbit components of 4p photoelectrons.

At the electron cyclotron resonance ion source of Atomki, transmission of 3 keV Ar^{7+} through densely packed nanocapillaries in polycarbonate (PC) foils was investigated. At the KVI Zenike LEIF laboratory, transmission of Ne^{7+} ions through capillaries in polyethylene terephthalate (PET) foils with diameter of 100 and 400 nm and with different length was investigated. They measured detailed time dependences of the intensity and angular distribution of the transmitted ions and neutralized projectiles at different tilt angles of the capillaries. In accordance with previous investigations, the guiding phenomena and subsequent blocking of the capillaries were observed. The blocking effect increased with the capillary length but decreased with the projectile energy. From the results it was concluded that the blocking is caused by the overcharge of the capillaries and most of the neutrals are created at the exit of the capillaries, which is contrary to the observations using shorter capillaries in PET foils.

Applications in Atomic Physics, Solid State Physics, Surface Sciences

Multiwall carbon nanotubes (MWCNTs) supported Pd-Au alloy nanocatalyst surfaces, modified by Ar^+ ion bombardment were studied using electron spectroscopic methods. These systems are important for fuel cell applications.

In the framework of a national project, the accumulation of uranium and transuranium compounds on the stainless steel structural materials of a VVER type pressurized water reactor was studied in sorption laboratory model at Paks. The results of the experiments indicate that the surface content of the transuranium compounds is less than one monolayer and at the same time the surface content of the uranium compounds, identifiable mainly in the form of UO_2 is larger than one monolayer.

Chemical structure of graphene layers deposited onto metallic substrates and the graphene-substrate interface layers were determined using XPS method in the frame of the Joint Korean-Hungarian Laboratory for Nanosciences, in cooperation with research groups from Budapest and South-Korea.

The researchers established the new Laboratory for Materials Science and Surface Physics, where among others an ESCASCOPE electron spectrometer with high lateral resolution and an X-ray monochromator, transferred from the Chemical Research Center of the HAS, has been installed.

The shapes of the Fe 1s and Ni 1s photoelectron spectra excited by synchrotron radiation and the results of their model calculations were compared to results of theoretical calculations published earlier. These results confirm the validity of the procedure applied for the correction of the experimental spectra for effects of electron scattering and the model used for describing the asymmetry of the 1s photoelectron lines.

In the case of a Ni nanolayer deposited onto Pd substrate, it was shown that the synchrotron radiation based on angular resolved hard X-ray photoelectron spectroscopy (AR-HAXPES)

method is applicable for determination of the attenuation length of high (5-10 keV) energy photoelectrons in metallic Ni.

Monte Carlo calculations have been performed for diamond and HOPG samples to test the effect of multiple scattering at relativistic electron energies.

For the first time, the temperature dependence of the ion-guiding has been measured. One control parameter to optimize guiding is the residual electrical conductivity of the insulating material. Thereby the effect of conductivity on the build up and removal of charge patches in the capillary can be studied. They showed that the glass temperature has a large influence on the transmission of ions and it can be compensated by adjusting the incident ion flux.

Transmission of electrons of energy 300-1000 eV through a single straight glass capillary of microscopic scale was studied. The experimental studies have revealed new information on both energy dependence and time (charge) evolution of the electron transmission process through the capillary sample.

Soft magnetic thin films prepared by electrochemical deposition were studied by a depth profile analysis method developed recently. This method is particularly suitable to study the zones being formed in the early phase of the electrodeposition of alloys. It has been demonstrated that in many cases when one component of an alloy is preferentially deposited, an initial zone is formed that is rich in the preferentially deposited component. This phenomenon is demonstrated for Ni-Cd, Ni-Sn, Fe-Co-Ni, Co-Ni and Co-Ni-Cu alloys. The composition change is confined to the initial 150 nm thick deposit, and it is the result of the interplay of the deposition preference and the depletion of the electrolyte near the cathode with respect to the ion reduced preferentially.

In thin layers of Ge, As and Ga produced by chemical vapour deposition (CVD) thermal diffusion processes were investigated during deposition. A method was developed to form a diffusion barrier on the surface of substrates. The thermal stability of ZnO layers produced by CVD was also studied. ZnO is an oxide material which is suitable to produce TCO layers (Transparent Conductive Oxide layers) in film solar cells. The results obtained in this field are applicable in the solar energy industry.

The electrical transport properties of Co/Pb ferromagnetic/superconducting films were studied at low temperatures. It was proved experimentally that Co-Pb alloy could be produced by electrochemical deposition.

Exploration of the energy dissipation efficiency of superparamagnetic particles in time-dependent magnetic field was performed developing a new phenomenological method.

Nanopowders have been produced by high energy ball milling from superionic crystals, promising materials for nano- and optoionics. The powders are used to prepare ceramics to study their physical properties. The nanopowders have been characterized by XRD technique.

A low noise, low power consumption preamplifier for CsI(Tl) scintillation detectors with silicon avalanche photodiode (APD) readout, intended for in-vacuum operation was constructed.

Using CsI(Tl) scintillation detector with silicon avalanche photodiode (APD) readout and digital particle discrimination improved proton/alpha separation energy thresholds of ≈1.2 MeV / 3.2 MeV have been achieved, compared with ≈ 2.1MeV / 4.5 MeV values for conventional Si photodiode readout and analog discrimination.

Factors limiting the achievable 3D position resolution of monolithic scintillation detectors and expressions describing the resolution were determined.

Electron energy loss processes during electron transport in InSb were investigated using their formerly developed model, accounting for plasmon creation and decay, too. It has been concluded that, contrary to earlier optimistic opinions, no good energy resolution can be expected with such detectors due to the large width of plasmons prevailing in the energy transfer, even despite its low bandgap value.

A position sensitive photodetector matrix consisting of a 18x18 array of silicon photomultipliers (SiPMs), 10 mm^2 active area each, intended for reading out a 35x35 element, 49x49 mm^2 total area LYSO needle crystal scintillator matrix for composing a MRI compatible small animal PET detector block prototype was tested.

Environmental Physics

A review paper has been submitted about the volcanologic hazards and geochronological study of young volcanic field in San Salvador. Age determination has been made on rhyolitic samples taken from Jastraba Formation, Central Slovakia Volcanic Field. Tertiary volcanic rocks were dated, collected in King George Island, Antarctica. Dating the time of transformations in low-grade metamorphics in Hungary and Croatia, as well as the study of change of formal K/Ar age of clay minerals in soil as an effect of vegetation and manuring was performed.

EnvironMICADAS, a dedicated ^{14}C accelerator mass spectrometer (AMS) specialized for environmental studies was sucessfully installed and tested in the Hertelendi Laboratory of Environmental Studies of Atomki. AMS ^{14}C sample preparation methods and lines were developed and evaluated for solid and liquid samples, for collagen extraction from bones and for groudwater dating from the dissolved inorganic matter of water samples. Development and evaluation of a special gas handling line with 8 parallel sample inputs for sealed tube graphitization method for AMS ^{14}C measurements was done. One year atmospheric aerosol ^{14}C record from Debrecen city using monthly average sampling with simultaneous airborne $^{14}CO_2$ measurements was collected.

A new standardization procedure which is better than the previously known methods has been introduced to the noble gas measurement process of fluid inclusions in speleothems. A new method for determination of oxygen and hydrogen stable isotope compositions in the water of chicken egg white has been developed. Additionally, correlation has been searched and found between the stable isotope ratios of the egg and the drinking water. Total dissolved gas samples of spring waters have been collected using a new passive, diffusion sampling technique. $^{3}H/^{3}He$-dating has been performed based on tritium concentrations and noble gas results obtained from the gas samples taken by the diffusion samplers.

Mass spectrometric measurement of air equilibrated water of a few microlitres, and interpretation of the measured and expected noble gas concentrations were performed.

A numerical model of geogas flow has been developed for describing the transport of mofetta gases in subsurface soil layers. Results were evaluated in correspondence with the gas yield measurements done at a monitoring well near a dry carbon-dioxide spa of Mátraderecske. The effect of soil surface temperature and of atmospheric pressure variations on the gas yield was analysed.

Atmospheric I-131, Cs-134 and Cs-137 concentrations have been recorded in Hungary during and after the Fukushima Nuclear Incident (2011, Japan). This was a study including dose-rate calculations. Further developments were: *i)* A new Se-79 measurement method for low and intermediate level radioactive waste, using Se-75 tracer produced in the Cyclotron Laboratory of Atomki. The Se-79 detection limit was reduced three orders of magnitude to Bq/l sample.

ii) A new data evaluation method in field (InSitu) gamma spectrometry method applied in the environmental monitoring network around the National Nuclear Waste Repository at Bátaapáti, Hungary. *iii)* A new liquid scintillation ^{14}C mesasurement technique for base solved carbonates which could significantly simplify the gas phase emission monitoring in the case of nuclear facilites. They also studied the ^{14}C impact of the Paks Nuclear Power Plant in a one decade (2000-2009) tree ring serie of a nearby tree.

Seasonal variation and long-term tendencies of composition and sources of atmospheric aerosol (particulate matter = PM) characteristics to the East-Hungary region were determined for the time period 1993-2011. The origin of emission episodes detected in the Debrecen urban aerosol were determined using hourly samples, nuclear analytical methods, single particle analysis and statistical analysis. Survey of PM pollution in educational institutions was performed in different seasons. Concentration, elemental composition and size distribution of aerosol were determined in different microenvironments. It was established that the concentration of PM inside the schools exceeded the 24-hour-limit recommended by WHO. Concentration, composition, and origin of indoor aerosol pollution were determined in four different workplaces of the Atomki. The effect of new windows in Atomki was observed too.

b) Relationship between science and society

In March 2011, the central idea of the traditional Physicist's Days of Atomki was the 100th anniversary of the discovery of the nucleus. During the afternoon lectures, students and other interested guests learned about Rutherford's discovery and its role in physics. The legendary experiment was also played by students in the courtyard, impersonating the colliding particles. There was an "open day" event in the program, when the preregistered visitors participated a guided tour in selected interesting laboratories of the institute. Taking into account the participation of students at the "special physics classes", also a traditional part of the program, there was a great interest for Physicist's Days in 2011; the number of visitors exceeded 1900.

In addition to the organized events, an external demand appeared for an unexpected outreach activity: the representatives and researchers of the institute provided information for the accompanying interest on the tragic accident in Fukushima, for both the media and the public.

Besides the Physicist's Days there were several opportunities to visit Atomki during the year. This usually meant that pre-registered groups of students visited one or more laboratories.

Researchers of Atomki presented numerous public lectures related to the events of the General Assembly of HAS in May in the topics of 'Rutherford's actuality', 'modern detector systems in nuclear physics', 'European perspectives of nuclear physics' and 'ion microscopy'. Considerable attention has been attracted by the "evergreen" topics of environmental physics: radiocarbon age determination.

In June, at the CERN exhibition in the Kölcsey Center, Debrecen, the visitors met the frontiers of particle physics. Atomki played a fundamental role in organizing the event. Young coworkers were in duty all the time, and held guided tours for the groups, making the exhibition enjoyable for the total of more than 500 visitors. Within the framework of an operation of the "Youth Team for the Nuclear Energetics", young Atomki researchers served in disseminating information related to nuclear energy at the CAMPUS festival in Debrecen.

In the summer of 2011 a so called Living Physics Summer Camp were jointly organized by the University of Debrecen and Atomki. The researchers hosted high school students in the

laboratory, who participated in a short research program, an experimental or computer simulation task during a one-week program.

In September, the topic of the Researchers Night was the phenomenon of superconductivity and its applications. Both the public lecture and the spectacular demonstrations were provided by Atomki's collaborators from the Technical University of Budapest. The visitors filled the auditorium, and the demonstration area.

In November, within the framework of the Hungarian Science Festival, lectures were delivered about renewable energy utilization, environmental physics, innovative drug development and about superconductors. In the course of the above mentioned Living Physics program, a talk about nuclear astrophysics was delivered in December.

Publishing educational articles is part of the promotional activity as well. In 2011, eight articles written by researchers of Atomki appeared on the columns of the "Természet Világa" and the "Fizikai Szemle", the city centre of Debrecen and the local newspapers provided information on Atomki too. The researchers appeared on the websites of OTKA and HAS, in the Atmosphere Photo magazine, and on Duna Television.

III. A presentation of national and international relations in 2011

The co-operations with national institutions worked in accordance with the previously established agreements and the living traditions in 2011 too. One should mention many departments of the University of Debrecen and the RMKI at the first place. The names of other partners make a long list. The Paks Nuclear Power Plant, the processing plant of the Radioactive Waste Management Nonprofit Ltd. (Püspökszilágy) and the environmental monitoring system of the National Radioactive Waste storage site (Bátaapáti) are partners of strategic importance. Here, the main activities of the institute are mission controlling, diagnosis of the parameters of the technological systems, and participation in waste classification.

In 2011, the institute strengthened its role in higher education, and maintained the traditional connections with the University of Debrecen. In the reported period, the researchers of Atomki delivered 745 lessons in the framework of 42 courses at the University of Debrecen (DE). Moreover, the number of the laboratory practices was 226, within 37 courses. Altogether 42 researchers participated in education activities. In undergradual educaton, the range of students was wide: physicists, physics teachers, IT specialists, software engineering mathematicians as well as ecology, environmental sciences, environmental management and agricultural engineering students were primarily taught (lectures, special laboratory practices, thesis, etc.). The PhD program is an even more important area. Seven of the twenty core members of the Physics Graduate School are researchers of Atomki. During the reporting period, 20 Phd students, 7 BSC and 7 MSC diploma workers and 14 undergraduate scientific volunteer (TDK) students worked at the institute. The total number of hours spent with supervising them was 2620. The scholarship program for "researcher students" continued in the institute. Under this umbrella there were seven fellow students working in Atomki in the spring semester and eight in the autumn semester.

International relations are essential for research in Atomki. As a continuation of the previous collaborations 60 topics can be listed, but the common work enriched by new elements.

Atomki researchers successfully work together with teams of various French institutes. They conduct joint experiments at the French National Heavy Ion Accelerator in Caen (GANIL) for a long time. From these collaborations, a number of outstanding results have been achieved, including one of the most important results of 2011, which was published in Nature. Atomki

was a participant in the FP7 consortium for preparing of the new accelerator center of GANIL. The project entered a new phase when the foundation stone of the new accelerator was laid in November. The European Commission permitted us to join to the construction of the accelerator centre (a European strategic infrastructure), with the help of the structural funds. The international advisory board of the Atomki warmly supports the intention to join, which may give a new boost to basic nuclear physics research.

In the field of nuclear astrophysics, four researchers participated in a set of measurements at the Laboratori Nazionali de Gran Sasso and the INFN LNS Nuclear Physics Laboratory Catania, in Italy.

The relation of the complex scaling and the Gamow-shell has been analysed by an Atomki researcher during a three month study tour, at the University of Tennessee. A new research program started at the high intensity gamma-ray source of the Duke University for exploring the splitting of the dipole giant resonance, based on the strongly deformed states before fission.

In 2011, an intense collaboration work has been performed within the framework of a Swiss-Hungarian trilateral research/development agreement (Isotoptech - MTA Atomki – ETH Zürich). The title of the program was 'Development of an EnvironMICADAS 14C AMS system for Hungary' (total value: 1.0 Mio €). An Atomki researcher spent 9 months in the Zürich Research Laboratory in Switzerland, where he took part in the development of the instrumentation and the methods (by the help of OTKA and Swiss Sciex mobilization scholarships)

Two researchers of the Atomki spent three weeks at the Bio-Nano Electronics Research Center in Japan, Toyo University (for the invitation of the Japanese side), and investigated the medical applications of ECR ion sources. Within a one year employement, an Atomki researcher studied ion-ion and photon-ion collisions at the Justus-Liebig University in Giessen. A researcher in the framework of the EFDA GOT program spent several months in Karlsruhe, working in tritium calorimetry. He continues to study this topic further.

Foreign researchers came to Debrecen for longer periods, too. A nuclear physicist from Bucharest spent the whole year here within the framework of her two-year OTKA fellowship. Two foreign researchers, one from Turkey and one from Portugal, worked in Atomki on their PhD works, by the support of Erasmus-scholarships.

The CHARISMA program has a distinguished role in the activity of foreign researchers in Debrecen. The preservation of cultural heritage in Europe is considered as an important task. In 2011, 10 foreign researchers performed experiments here from Belgium, Bulgaria, Greece, Germany and Romania. The measurements took 17% of the full VdG-5 working time.

In the field of international collaboration, new agreements were signed in 2011. Atomki joined to the international program EXOGAM2, which helps to develop the nuclear physics research in Caen, France. The institute signed a collaborative contract with the German Physikalisch-Technische Bundesanstalt Braunschweig und Berlin for doing atomic physics research. The institute established a collaboration contract with the institute of the University of Oradea in the field of education and research, and signed a cooperation agreement with the Huazhong University (China) for starting a liver surgery research with computer support.

The institute joined to a multilateral collaboration, which aims to implement a proton therapy project in Debrecen (Members: the University of Debrecen, DEOEC, the Municipality of Debrecen, Proton Therapy Provider Co., Prague and Atomki)

During Hungary's EU Presidency, the Week of Innovative Regions in Europe 2011 (WIRE2011) conference held in Debrecen between June 7-9, 2011 with the active

participation and co-organizing work of Atomki. The conference participants also visited the institute. The 37th Meeting of the European Strategy Forum on Research Infrastructures (ESFRI) was held in Atomki on 6th June. A training course of the Central European FLAME innovation project took place in the institute from 11 to 14 June. The COST Workshop on Dynamics and Control of Atomic and Molecular Processes Induced by Intense Ultrashort Pulses was also held in Atomki between September 28 to 30, 2011. The External Advisory Board of Atomki held its meeting at the institute on October 5-6, 2011. The international meetings took place in the newly renovated lecture hall and meeting room.

IV. Brief summary of national and international research proposals, awarded in 2011

Domestically, Atomki received the largest support from the National Development Agency (NDA), the Radioactive Waste Management Inc, the National Innovation Office (NIH, NKTH, NKFP), the Paks Nuclear Power Plant, the NKTH - OTKA and OTKA organizations, and internationally from the European Union.

The institute had 91 projects in 2011, of which 37 had the total amount over 10 million HUF, and 22 projects above 20 million HUF. These 22 projects are listed below, with the amount of support to Atomki in total, and the amount for 2011.

NDA: Complex development in building energetics, 342,208 - 223,208 thousand HUF
NDA: PRIZMATECH Cluster, 36,143 - 6,971 thousand HUF
Radioactive Waste M. Inc.: Püspöksz. RHT area. Samples exam., 108,788 - 27 073 thousand HUF
NKTH: Advanced imaging system, 106,550 - 68 454 thousand HUF
NKTH: The diagnosis of the chemical state of the comp., 71,250 - 71,250 thousand HUF
NKTH: LHC Grid center of Debrecen, 64,084 - 64,084 thousand HUF
NKTH: New generation, environmentally friendly thin-film solar cells, 40,000 thousand HUF
NKFP: Multi-modality imaging system, 82 112 - 20 740 thousand HUF
Paks Nuclear Power Plant: Difficult to measure determination of isotopes 47,620 - 11,270 thousand HUF
NKTH - OTKA: Search for New Physics at CERN, 29,359 - 11,784 thousand HUF
NKTH - OTKA: The 3He + 4He reaction formation in the Sun, 24,000 - 12,000 thousand HUF
OTKA: Nucleosynthesis of heavy elements, 21 998 - 8117 thousand HUF
OTKA: Fundamental interactions and exotic nuclear states, 23,157 - 3,231 thousand HUF
EU: Astrophysical p-process, 750000 EUR - 214731 EUR
EU: Euratom Fusion Training, 149227 EUR - 14623 EUR
EU: CHARISMA program, 197000 EUR - 35040 EUR
EU: The future's laboratory of materials science, 105723 EUR - 11556 EUR
EU: Collective excitations of atomic ionization, 100000 EUR - 35900 EUR
EU: Surface wear test, 83350 EUR
EU: Development of E + E-detector, 79500 EUR - 38425 EUR
EU: Tritium education program, 65000 EUR - 24000EUR
EU: Development of artificial diamond-based detectors, 34242 EUR - 24202EUR

V. List of important publications in 2011

Bene E, Vértesi T, Englman R
Reciprocity in the degeneracies in some tetra-atomic molecular ions.
JOURNAL OF CHEMICAL PHYSICS **135:**(8) *Paper 084101.* (2011)
IF: 2.920*

Bosi M, Attolini G, Ferrari C, Frigeri C, Calicchio M, Rossi F, et al. (9), Vad K, Csik A
Effect of temperature on the mutual diffusion of Ge/GaAs and GaAs/Ge.
JOURNAL OF CRYSTAL GROWTH **318:**(1) *pp. 367-371.* (2011)
IF: 1.737*

Caciolli A, Mazzocchi Ch, Capogrosso V, Bemmerer D, Broggini C, Corvisiero P, et al. (30), Elekes Z, Fülöp Zs, Gyürky Gy, Somorjai E
Revision of the 15N(p, gamma)16O reaction rate and oxygen abundance in H-burning zones.
ASTRONOMY & ASTROPHYSICS **533:** *p. A66.* (2011)
IF: 4.410*

Cederwall B, Moradi FG, Back T, Johnson A, Blomqvist J, Clement E, et al. (57), Nyako BM, Algora A, Dombradi Z, Gal J, Kalinka G, Molnar J, Sohler D, Timar J.
Evidence for a spin-aligned neutron-proton paired phase from the level structure of Pd-92.
NATURE **469:**(7328) *pp. 68-71.* (2011)
IF: 36.101*

Dassanayake B S, Bereczky R J, Das S, Ayyad A, Tôkési K, Tanis J A
Time evolution of electron transmission through a single glass macrocapillary: Charge build-up, sudden discharge, and recovery.
PHYSICAL REVIEW A **83:**(1) *pp. 2707--7.* (2011)
IF: 2.861*

Hori M, Sótér A, Barna D, Dax A, Hayano R, Friedreich S, et al (12), Horváth D.
Two-photon laser spectroscopy of antiprotonic helium and the antiproton-to-electron mass ratio.
NATURE **475:**(7357) *pp. 484-488.* (2011)
IF: 36.101*

Huszank R, Szikra D, Simon A, Szilasi SZ, Nagy IP
He-4(+) Ion Beam Irradiation Induced Modification of Poly(dimethylsiloxane). Characterization by Infrared Spectroscopy and Ion Beam Analytical Techniques.
LANGMUIR **27:**(7) *pp. 3842-3848.* (2011)
IF: 4.268*

Kardos A, Papadopoulos CG, Trocsanyi Z
Top quark pair production in association with a jet at NLO accuracy with parton showering.
PHYSICS LETTERS B **705:**(1-2) *pp. 76-81.* (2011)
IF: 5.255*

Kern Z, Fórizs I, Pavuza R, Molnár M, Nagy B
Isotope hydrological studies of the perennial ice deposit of Saarhalle, Mammuthöhle, Dachstein Mts, Austria.
THE CRYOSPHERE **5:** *pp. 291-298.* (2011)
IF: 3.641*

Kiss G G, Szücs T, Rauscher T, Kertész Zs, Fülöp Zs, Gyürky Gy, et al (10), Farkas J, Elekes Z, Somorjai E
Determining reaction cross sections via characteristic X-ray detection: α-induced reactions on 169Tm for the astrophysical γ –process.
PHYSICS LETTERS B **695:**(5) *pp. 419-423.* (2011)
IF: 5.255*

Krasznahorkay A
Tunneling through triple-humped fission barriers.
In: Vértes A, Nagy S, Klencsár Z, Lovas R, Rösch F (szerk.) Handbook of Nuclear

Chemistry: 2nd edition., Heidelberg; New York: Springer-Verlag, 2011. *pp. 281-318.* (ISBN:ISBN 978-1-4419-0719-6)

Navascués M, Vértesi T
Activation of Nonlocal Quantum Resources.
***PHYSICAL REVIEW LETTERS* 106:** *p. 060403.* (2011)
IF: 7.621*

Nándori I
Bosonization and functional renormalization group approach in the framework of QED2.
***PHYSICAL REVIEW D PARTICLES AND FIELDS* 84:**(6) *9 p. Paper 065024.* (2011)
IF: 4,964*

Rácz A, Salamon P, Vertse T
Trajectories of S-matrix pole in a new finite-range potential.
***PHYSICAL REVIEW C NUCLEAR PHYSICS* 84:**(3) *Paper 037602.* (2011)
IF: 3.416*

Racz R, Biri S, Palinkas J
ECR plasma photographs as a plasma diagnostic.
***PLASMA SOURCES SCIENCE & TECHNOLOGY* 20:**(2) *Paper 025002.* (2011)
IF: 2.218*

Sohler D, Grevy S, Dombradi Z, Sorlin O, Gaudefroy L, Bastin B, et al. (40), Elekes Z, Kuti I
Spectroscopy of 39,41Si and the border of the N=28 island of inversion.
***PHYSICS LETTERS B* 703:**(4) *pp. 417-421.* (2011)
IF: 5.255*

Stolterfoht N, Hellhammer R, Sulik B, Juhász Z, Bayer V, Trautmann C, et al. (8)
Evidence of blocking effect on 3-keV Ne^{7+} ions guided through nanocapillaries in polycarbonate
***PHYSICAL REVIEW A* 83:**(1) *10 p. Paper 012901.* (2011)
IF: 2.861*

Szilasi SZ, Budai J, Pápa Z, Huszánk R, Tóth Z, Rajta I
Refractive index depth profile and its relaxation in polydimethylsiloxane (PDMS) due to proton irradiation.
***MATERIALS CHEMISTRY AND PHYSICS* 131:** *pp. 370-374.* (2011)
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Activation cross-sections of deuteron induced nuclear reactions on gold up to 40 MeV.
***NUCLEAR INSTRUMENTS & METHODS B* 269:**(12) *pp. 1389-1400.* (2011)
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Valastyán I, Kerek A, Imrek J, Hegyesi Gy, Kalinka G, Molnár J, et al. (7)
LSO based dual slice helical CT and PET demonstrators.
***NUCLEAR INSTRUMENTS & METHODS A* 633:** (SUPPL1) *pp. 300-302.* (2011)
IF: 1.142*

Vodila G, Palcsu L, Futo I, Szanto Z
A 9-year record of stable isotope ratios of precipitation in Eastern Hungary: Implications on isotope hydrology and regional palaeoclimatology.
***JOURNAL OF HYDROLOGY* 400:**(1-2) *pp. 144-153.* (2011)
IF: 2.514*