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I. Main duties of the research unit between the 1st of January and the 31st of August, 2019

The main duty of the institute in fundamental research focusing on atomic, nuclear and particle physics, as well on nuclear astrophysics was carrying out aligned, cutting edge research work with large-scale international collaborations, making balanced use of the local research infrastructure and that of the leading international research centres. An important task of the reporting period was preparation for the administrative and technical closing of the GINOP projects (operative program for economic development and innovation, funded by the government from EU sources) that started in 2016. Further tasks in 2019 were participating in university education and training of PhD students as well as that of international specialists. Besides the preparation of the usual reports, in the first months of the year new and exceptional tasks were compiling the documents necessary for the three-year audit of the institute and preparing the application to the Thematic Excellence Programme of the National Research, Development and Innovation Office (NKFIH).

II. Outstanding research and other results between the 1st of January and the 31st of August, 2019

II. a) Outstanding research results

Theoretical Physics

Genuinely high-dimensional entanglement having high Schmidt number is a useful resource in quantum communication. For example, high-dimensionally entangled systems exhibit better noise tolerance compared to low-dimensionally entangled systems. On the other hand, the so-called bound entangled states represent a very weak form of entanglement in nature. From these quantum states, given their infinite number of copies, no pure state entanglement can be distilled. The existence of these two distinct types of entanglement properties raises the question of whether there exist quantum states which possess both properties at the same time. This question has been answered affirmatively by constructing analytically bound entangled states with high Schmidt number. In particular, for any $d \geq 4$ dimensional component Hilbert space a linear $d/2$ scaling of its Schmidt number in the local dimension d could be attained.

It is known that in Coulombic quantum systems the wave functions must be described by the so-called Kato's cusp conditions. The importance of the fulfilment of the Kato cusp condition has been demonstrated for double photoionization. New basis functions satisfying these conditions have been proposed. They were constructed simply as a special linear combination of the standard Hylleraas or Kinoshita type wave functions. It was shown that the ground-state properties of He and H^- can be derived accurately using these functions too.

It has been shown within the Elliott model that the nuclear deformation is a consequence of the spontaneous breaking of the rotational symmetry. This statement turned out to be true not only for quadrupole deformation (which had been discussed beforehand in other models as well), but also for octupole and molecular configurations. The methodological interest of this work stems from the fact that the general mechanism of the spontaneous breaking is discussed in relation with the familiar rotational symmetry within a simple model, therefore, it may help the understanding of this important phenomenon.

A new method has been developed for the determination of shape isomer states of atomic nuclei. Such theoretical studies have been based so far on the local minima of the potential energy surface. The new method determines the shape isomer states from the stability and self-consistency of the SU(3) symmetry. Since the quantum numbers of this symmetry and quadrupole deformation mutually determine each other, this method can also be considered as an investigation of the stability and self-consistency of the deformation. The two methods give identical, or very similar results for light nuclei.

The finite square well potential was extended for the case of PT-symmetric quantum mechanics, i.e. a theory, which is invariant with respect to the simultaneous space and time reflection. This work was inspired by the similar extension of the Rosen-Morse II potential, which has similar shape and which was found to exhibit unusual features among PT-symmetric potentials. The general solutions were determined, and closed formulas were derived for the T(k) transmission and R(k) reflection amplitudes. In order to identify the bound states, the poles of T(k) were located. It turned out that only solutions with real energy eigenvalues can be found, in agreement with the results concerning the PT-symmetric Rosen--Morse II potential. This finding was attributed to the asymptotically non-vanishing imaginary potential components.

The degree of structural disorder plays a decisive role in the fracture of heterogeneous materials. Increasing the amount of disorder, fracture processes are accompanied by a more intense crackling activity, which allows for a more accurate forecasting of the imminent catastrophic failure event. It was demonstrated that in the limit of extremely high disorder, statistical features of crackling noise depend on the size of the system, which implies that reliable failure forecasting is only possible above a critical system size. It was pointed out that the degree of disorder has both a lower and an upper bound, beyond which the crackling noise does not provide sufficient information about the damage state of the system, making the failure of highly brittle and ductile materials unpredictable.

Particle Physics

At the critical temperature of QCD, an external magnetic field has two opposite effects on strongly interacting matter. On the one hand, it affects valence quarks and enhances the quark condensate (catalysis). On the other hand, it also affects sea quarks and this effect suppresses the condensate (inverse catalysis). These two effects were studied as a function of the quark mass and it was found that for quarks heavier than a critical mass, magnetic catalysis dominates in the whole transition temperature region. This can provide an explanation of some controversial lattice results that appeared in the literature in the last few years.

In the high-temperature phase of QCD, instantons appear as a gas that becomes more and more dilute as the temperature increases, and eventually should become an ideal gas. It is important to determine the temperature above which the instanton gas can be considered to be an ideal gas for practical purposes. A method was developed to count the number of instantons and antiinstantons and their distribution, and it was used to show that in the so-called quenched approximation the instanton gas becomes an ideal gas right above the phase transition temperature.

The role of the Berezinskii-Kosterlitz-Thouless (BKT) phase was investigated in coupled XY models. The effect of a linear tunneling coupling was studied between 2D systems, each separately exhibiting the topological BKT transition. In the uncoupled limit, there are two phases: one in which the one-body correlation functions are algebraically decaying and another one with exponential decay. When the linear coupling is turned on, a third BKT-paired phase emerges, in which one-body correlations are exponentially decaying, while two-body correlation functions exhibit power-law decay. Numerical simulations were performed in the paradigmatic case of two coupled XY models at finite temperature, and it was found that for any finite value of the interlayer coupling, the BKT-paired phase is present. A picture of the phase diagram was provided using a renormalization group approach.

The responsibility of the Atomki group during the data collection periods of CERN CMS were the operation of the barrel muon position monitoring system, carrying out possible repair works, data evaluation, and the determination of the karma positions. Altogether 71 measurement cycles have been completed during the reporting period.

The work related to the calibration of the readout boards of the altogether 164 GE1/1 chambers has been completed successfully. Making use of the precision moving table, the scanning of the complete surface of the boards, as well as the determination of the position of the read-out strip electrodes has been completed. In collaboration with the CERN Survey Group, a photogrammatic method has been developed, by which the position of the reference elements located on the assembled chambers has been determined with respect to the external frames of the chambers. The measurement, also based on a photogrammatic method, which aims at determining the relative position of the members of superchambers composed of two chambers and to be built into the CMS, has been started.

The European Spallation Neutron Source (ESS) is a major research infrastructure that is under construction in Lund, Sweden, under a joint European project. Atomki is responsible for developing and delivering the local radiofrequency protection system of the medium beta and large beta sections. In 2019 Atomki completed the development and the manufacturing of the fast interception unit, and delivered the prototype of the slow interception unit to ESS. Based on the experience obtained during the in-site tests, ESS developed further the slow units and prepared the final design.

Nuclear Physics

Nuclei with magic number of protons and/or neutrons are sphere-like and their structure is particularly stable. Neutron-rich nuclei around ^{78}Ni were studied by an international collaboration in the word-leading radioactive ion beam facility at RIKEN, Japan. The obtained energy of the first excited state of ^{78}Ni provides a direct evidence of the doubly

magic character of this nucleus. Beside this spherical state, a competing deformed structure was also identified at a similar energy, which indicates the breakdown of the magicity beyond this stronghold.

In an international collaboration, researchers of Atomki studied proton knock-out reaction in very neutron-rich nuclei using radioactive ion beams at RIKEN, Japan, and found that the cross sections are systematically higher, when protons are removed from nuclei containing even number of protons compared to nuclei with odd number of protons. The effect was attributed to the higher density of bound-state levels in odd-Z daughter nuclei, compared to even-Z ones.

The Gamow-Teller (GT) transitions in the ^{18}F nucleus have been studied using the ^{18}O(^{3}He,t)^{18}F reaction. The obtained B(GT) reduced transition strength values were consistent with the available (p, n), (p, p), and β-decay data. The results of shell-model and quasiparticle-random-phase approximation (QRPA) calculations indicate constructive contributions from various configurations to the ^{18}F ground state, suggesting that this state is the low-energy super GT state.

Atomki researchers participated in the first experiment at the cyclotron of the Center Bronowice (CCB) in Krakow. Proton beams accelerated with the IBA Proteus C-235 cyclotron are in the 70-230 MeV energy range. In the reported measurement, the energy of scattered protons at the incident beam energy of 85 MeV and emitted γ rays from the excited ^{208}Pb target were measured in coincidence. During the experiment, excitations in the energy region of the Giant Quadrupole and Dipole Resonances, as well as the Pygmy Dipole States were observed.

Electron-positron pairs from the electro-magnetically forbidden M0 transition depopulating the 21.01 MeV 0^- state in ^{4}He were observed in Atomki. A peak was observed in the e^+e^- angular correlations at 115^o with 7.2σ significance, which could be described by assuming the creation and subsequent decay of a light particle with mass of m_Xc^2=16.84 MeV. The obtained mass value agrees very well with that derived for the X17 boson from the previous ^{8}Be experiments.

Wobbling motion, which is related to the triaxial nuclear shape and which is an analogue of the precession motion of rigid bodies, has been identified in the ^{105}Pd nucleus. This nuclear motion is characterized by a special set of excited states and by the special properties of gamma quanta emitted by these states. These excited states and their decay properties were studied using the EUROBALL and the DIAMANT detector systems in an international collaboration. This work provides the first observation of wobbling motion in the A~100 nuclear mass region.

Rotation of the ^{130}Ba nucleus has been studied in an international collaboration using the GALILEO detector array. It has been found that the nucleus is soft and its shape can be changed in its medium-spin states, whenever a nucleon pair is broken up. In these states the nucleus has different shapes and rotates differently depending on which nucleon pair is broken and how the angular momenta of the nucleons are aligned relative to the symmetry and rotation axes. A new arrangement in this nuclear region has been found, in which a prolate shape is formed due to a broken neutron pair, but the rotation axis does not coincide with any of the principal axes.

Using a particle accelerator operated by the international collaboration LUNA deep underground at Gran Sasso, Italy, the nuclear reactions $^{18}O(p,\gamma)$, $^{18}O(p,\alpha)$ and $^{23}Na(p,\gamma)$ were studied at an extremely low level of the disturbing background radiation. Due to the special capabilities of the underground laboratory, the measurements could be performed at very low energies for all the three reactions. For the reactions $^{18}O(p,\gamma)$ and $^{18}O(p,\alpha)$, the strength of the resonance located at 90 keV as well as that of the resonance at 140 keV for the reaction $^{23}Na(p,\gamma)$ could be determined with unprecedented precision. These results substantially constrain the uncertainty of nucleosynthesis calculations. With the invitation of the European Physical Journal, a review was written on the activation technique in nuclear astrophysics.

Applied Nuclear Physics

The elemental composition of medieval glass objects was determined in collaboration with Trans-National Access (TNA) users within the IPERION CH project. The objects did not show signs of recycling, and the objects could be grouped according to their composition. The results contribute to the better understanding of the glass production in medieval Tuscany. Also within the IPERION CH TNA program, the trace element level composition of inclusions in ceramics was determined using the nuclear microprobe of Atomki.

The light yield of a 1”x1” EJ-299-34 plastic scintillator was measured at E_n = 5.9, 9.4 and 12.4 MeV neutron energies using quasi-monoenergetic d+D fast neutrons. The results enable application of the Pulse Height Response Spectrometry (PHRS) method for unfolding neutron spectra that cover broad neutron energy range, when the scintillator is used as the neutron detector.

A method was proposed, which solves issues about the determination of a specific materials science property measured by Atomic Force Microscopy (AFM). The method was demonstrated on PDMS (polydimethylsiloxane) polymer, which was irradiated with various fluences of ion beams to control their elastic properties from rubbery to glassy state. This method, if applied correctly, can significantly increase the reliability of AFM force-curve evaluation.

A method was introduced in the practice of producing the ^{7}Be radioisotope from those carbon containing samples, for which activation is possible only by ^{3}He bombardment. The method was successfully used in different kinds of samples. In order to determine the eventual damage of the samples during the activation, sample surfaces irradiated with various doses have been investigated with further surface physics methods in order to determine the kind and measure of changes produced by the activation.

Differential cross sections were measured for proton induced γ-ray emission (PIGE) from the reactions $^{23}Na(p,p'\gamma)^{23}Na$ (E_γ = 441 and 1636 keV) and $^{23}Na(p,\alpha'\gamma)^{20}Ne$ (E_γ = 1634 keV) with proton energies from 1.77 to 3.02 MeV. These reactions are important for analytical purposes. The cross section data were validated by measuring thick target yields. This work was carried out within a collaboration coordinated by the International Atomic Energy Agency. The results contribute to the more accurate non-destructive determination of the sodium content of art and archaeological objects, as well as that of environmental samples. The data are available in the IBANDL data base.

A new, fast method has been developed in collaboration with the University of Debrecen for the fenotyping of plants using the ^{52}Mn radioactive PET isotope, in order to test the stress tolerance of maize hybrids with a PET camera. The so-called affibodies have been engineered by artificially generated receptor-active portions of antibodies and have been used to diagnose tumor cells in cell cultures using PET radioisotopes bounded by a bifunctional complexing molecule.

Cross sections of charged particle induced nuclear reactions were measured on Al, Ti, Hf, Ni, Ca, Ho, Tm, Y, Yb and Zr targets in various energy regions. The experiments were performed in collaboration with research centers from Japan, Belgium and South-Africa. The new cross-section values can be used for creating and improving reference excitation function data bases, for checking the predicting power of different nuclear model codes, as well as for enhancing the efficiency of various practical applications.

Atomic and Molecular Physics

The energy and angular distribution of negatively and positively charged ions emitted from water molecules after irradiation by 6.6-kev O^+ ions were investigated experimentally. The distributions of the oppositely charged ions showed great similarity. The H^- to H^+ ratio was found to be 1:100 independently of the energy and the angle. The experimental findings were interpreted by theoretical models of different levels. The model calculations showed agreement with the experiments and indicated the importance of kinetic energy release stemming from excitations. The present observations confirm the earlier findings that in ion induced fragmentation by singly charged ions, the charge state of the emitted fragments follow simple statistical laws.

An electron beam characterized by high-angular discrimination, was used to measure the total (elastic plus inelastic) cross section of water in the energy range 3–100 eV. Average (rotationally and vibrationally summed) differential elastic cross sections were obtained at small scattering angles ($\simeq$1°), which provided the first test of theoretical predictions in an angular region experimentally unexplored until now. The experimental data were in rather good agreement with results of the ab initio R-matrix method.

The question of the coherence properties of projectile ions is one of the most discussed topics in the field of atomic and molecular collisions. Not all the parameters for the emerging fragments are measured directly in a given measurement, as the remaining ones are determined by using conservation laws. This fact has a significant impact on the role of the discussed coherence, which was demonstrated in a theoretical study for the 75 keV p-He collision system. It was found that the experimental findings are only partially explained by the incoherence of the projectile beam, as various different collision mechanisms and target polarization seem to play more important role.

A significant innovative development was carried out at one of the facilities of the Accelerator Center. The magnetic trap of the more than 20-years old home-made ECR ion source was re-designed and modified, resulting in important prompt forward steps in two fields. 1: the intensity of the extracted highly charged ion beams increased by 50-100%. 2: the modified magnetic trap and its fine-tuning enables the creation of the plasma state of

materials both in stable and unstable regimes and also at their border. Thus a facility was created, presently unique in the world in its class, which is suitable for the investigation of plasma instabilities. These studies are of fundamental importance, e.g. for fusion research.

Photo-induced processes of the endohedral fullerene ions $Sc_3N@C_{80}^+$ és $Sc_3N@C_{80}^-$ were investigated on the beam line of the PETRA III synchrotron (DESY Hamburg) in the 30-50 eV and 280-420 eV photon energy ranges. The emphasis of the experiments was on the specific effects of the encapsulated trimodal nitride cluster on the observed reactions. Single and double ionisation of the molecules accompanied by the release of C_2 dimers were also observed. These results are also relevant for astrophysics and life sciences.

Cross sections and rate coefficients for the dissociative recombination of CH^+ induced by low-energy electrons were computed with the inclusion of rotational interactions. The results were published in the final article of series of papers that deals with electron induced processes of CH^+ in the temperature region 10 – 10000 K.

The process of electron capture was investigated in the $p + H_2 \rightarrow H(1s) + H_2(1s\sigma)$ collision. Using the framework of the Born–Oppenheimer approximation, the distorted-wave-Born model was extended to consider the influence of vibrational processes. Non-dissociative and dissociative capture cross sections were calculated for 20–300 keV incident proton energies, and were found to be in qualitative agreement with the measured data. At low impact energies the vibrational distribution of the H_2^+ ions showed good agreement with the Franck–Condon factor, which represents the overlap between the initial and final vibrational states.

Development and testing of a high-resolution electron spectrometer were carried out with the support of the National Excellence Programme, Hungary.

The currently available information on cross sections and reaction speeds for elementary electron-molecule (H_2, N_2, O_2, NO, CO) collision processes relevant for atmospheric plasmas (in Earth, Mars, …) was extended and summarised in a book chapter.

Surface Physics

In the frame of cooperation between the Polish Academy of Sciences and the Hungarian Academy of Sciences, reduced graphene oxides were studied. Graphene oxide (GO) samples were produced by a modified Hummer's process which were reduced (rGO) by different reducing agents. The rGO specimens contained several small plates with the thickness of a few atomic layers, the number of which was determined by X-ray diffraction and reflexion electron energy loss spectroscopy (REELS).

Fe_3O_4 magnetic nanoparticles (MNPs) were functionalized by biocompatible adsorbed molecules. The f-MNPs gap energies were determined by REELS measurements. The band gap energy decreased with increasing particle size. The layer thickness of the functionalized part of the particles was 0.7-1.3 nm.

Metalloid semiconductors (Si and Ge) having very intensive plasmon peaks were studied by REELS. The optical constants, i.e. refractive index, extinction coefficient and complex dielectric function, were calculated from energy loss function of Si and Ge by the Kramers-

Kronig analytical formula. The applied energy region was a few keV, so the received information concerns the top surface layers of solid materials.

The change in surface elemental composition of a few nanometer thick layer was studied by low-energy ion scattering technique. The is the result of thermally induced atomic motions. In copper/silicon systems, the activation energies of low-temperature nanodiffusion processes were determined. The atoms appeared on the surface due to grain boundary process were organized by surface diffusion and Volmer-Weber type layer growth mechanism.

The change in V concentration of the TaV_2 thin layer inside the Ta/TaV_2/V layered structure was measured as a function of annealing time. It was found that the chemical composition of the TaV_2 layer was changed due to dissolving of this layer into adjacent layers.

A CaSi layer with strong surface bonding to medical implants was produced by electrospray technique. This technique can improve the surfaces of medical implants from the point of view of application.

The modifying effect of low-energy ion sputtering on ionization probability of PbTe elements was studied. The results received helped the better understanding of the process of preferential sputtering, which is important for depth profile analyses based on sputtering.

Environmental Science

In the field of geochronology, a study was published on the volcanostratigraphy and evolution of the Telkibánya Lava Dome Field. Volcanological mapping of the area described previously unidentified members of stratigraphy, with two generations of lava domes and the Abaújvár-Telkibánya Ignimbrite unit separating them. The K/Ar measurements (2 samples) have narrowed the interval of volcanic activity between 11.47 ± 0.19 and 11.56 ± 0.15 million years.

The eruption chronology of the Ciomadul volcanic complex, the youngest active volcano in the Carpathian-Pannonian Region, was determined by combined zircon U-Th and (U-Th)/He geochronology. The main lava dome complex formed at ca. 160-90 years ago, whereas the explosive eruptions occurred at ca. 50 and 30 years ago, forming the present-day shape of the volcano. The activity of the whole volcanic dome field can be divided into two main stages: the period from 1 to 0.3 million years ago is characterized by the formation of the small-volume lava domes whereas in the last 200 thousand years the intensity of the volcanic activity largely increased.

A comparative study was undertaken to adopt and evaluate a radiocarbon (^{14}C) preparation procedure for accelerator mass spectrometry (AMS) measurements of cremated bones at the Atomki AMS laboratory, including various types of archaeological samples (cremated bone, bone, charcoal, charred grain). Based on the infra-red spectroscopy and ^{14}C analyses, the chemical pretreatment protocol was found to be successful in removing contamination from the samples. Good reproducibility of ^{14}C ages was obtained for the 0.2–0.3 mm fraction of blind-tested cremated samples.

A multi-tracer investigation was applied to identify the recharge conditions and isotope hydrological character of four aquifers in the Lom depression (Northwest Bulgaria) using environmental isotopes ($\delta^{18}O$, $\delta^{2}H$, $\delta^{13}C$, ^{3}H, ^{14}C) and noble gases. The mean residence time of groundwater samples represent the last twelve thousand years. In addition to a recently recharged groundwater sample, some samples represent the early Holocene and samples closely correspond to the late Pleistocene or the transition time between the early Holocene – late Pleistocene. Noble gas recharge temperatures of this latter samples indicate a cooler climate.

A study was conducted to explore the noble gas and carbon isotope geochemistry of the gas emissions from the youngest volcano from the Carpathian-Pannonian Basin, the Ciomadul. The area is characterized by the existence of intense gas emissions, especially CO_2, in the form of free gas, that has a high flux, with a total output up to 8000 tonnes per year. The study, based on the isotopic ratios of the helium isotopes and carbon isotopes ($\delta^{13}C_{CO2}$) shows a magmatic contribution to the volatiles emerging from the study area, up to 60-80%. Considering the chemical characteristics of the Ciomadul dacite, and the isotopic ratios of the fluids, it was concluded that the mantle litosphere beneath Ciomadul is strongly metasomatized and primary helium isotopic ratios could have been modified by postmetasomatic ingrowth.

In a critical comment for a review paper, it was pointed out that the inaccurate descriptions of the anatomical structure of plants may result in incorrect conclusions with respect to evaluating the effects of environmental factors on them. The building of a phytolith reference collections for palaeoecological studies in the Carpathians has been started. This was the first time that a characteristic phytolith morphotype was described in *Picea abies* needles and phytoliths of three important species have been screened in detail. As a result, the element content of phytoliths has taxonomic relevance.

Concentration, composition and possible sources of particulate matter pollution (PM) was determined on trams in the downtown of Debrecen. 3 to 9 times higher concentrations were measured on the tram cars than in the outside air. The highest pollution level was detected in the old-type tram cars in heating season. The outdoor air, resuspended dust, the abrasion of the railways and the upper wire and cleaning materials were identified as the main sources of PM pollutions inside the vehicles. The nearby road construction works also effected the pollution level inside the trams by a great amount.

Radiocarbon (^{14}C) analysis was performed on Japanese cedar tree rings from Koriyama, (Fukushima, Japan). The primary aim of the study was to detect any ^{14}C release from the Fukushima Dai-ichi nuclear power plant accident that occured on 11 March 2011. ^{14}C levels in Japanese tree rings were assessed for the period of 1990–2014. A trajectory model was constructed to investigate the forward and backward air mass trajectories at the area of the power plant and the sampling site. The modeling data show that the air masses mainly moved to the Pacific Ocean, both during March 2011 and during the growing season (March–September). During the period 1990–2014 there was no significant ^{14}C excess in any of the samples, but there was a detectable Suess effect in almost every tree ring sample.

Fallout isotope ($^{210}Pb_{ex}$, ^{137}Cs and ^{241}Am) based dating has been carried out on the near-surface sediment from Lake Bolătău-Feredeu (Romania). The motivation was to improve the chronology of this recent section in connection with significant fluctuations observed in

sediment accumulation rates. Significant changes have been observed in the depth distribution of both the particle size distribution and the elemental/isotopic composition of the sediment record, which is most likely related to the variation observable in the intensity and volume of precipitation in the catchment. The obtained high-resolution records can serve as a regional benchmark for similar studies.

II. b) Science and society

Since the major programs aimed at the general public (e.g. *Physicists' Days*) are usually organized during the autumn months by Atomki, there were no central dissemination programs scheduled in the reporting period.

In individual organization, Atomki hosted 7 groups with 112 visitors until the 31st of August (primary, secondary school pupils, university students and interested adults), who spent there 225 visitor hours in total. The program was adjusted to the knowledge level and interest of the groups, and it contained lectures accompanied by experiments and laboratory visits. In the visitor centre the main features of radioactivity and its measuring methods were introduced, while cryophysical demonstration taught visitors about phenomena taking place at very low temperature.

The two publications written by the researchers of Atomki in 2018 for popular scientific magazines are available (in Hungarian) on the webpage of Atomki.

Videos recorded during the lectures of *Researchers' Night* and *Physicists' Days* organized in the past few years are available at the most popular file sharing portal. These videos attracted about 21 thousand viewings during the reporting period.

159 appearances of Atomki and its researchers were recorded in the Hungarian media in the reporting period.

III. Presentation of national and international R&D relations between the 1st of January and the 31st of August, 2019

The collaborative research activities of the institute are traditionally carried out in terms of large international collaborations (e.g. CERN-CMS, LUNA, RIKEN, etc.) and bilateral cooperations of various level. Atomki researchers joined two new projects of the International Atomic Energy Agency (IAEA). New government level bilateral cooperations were established with French and Moroccan institutes, while new inter-institutional collaborations were signed primarily with universities and organizations from the countries surrounding Hungary (Babes-Bolyai University, Cluj; Belgrade University; Charles University, Prague; Sapientia Transylvanian Hungarian University, Slovakian Geological Institute, Slovenian Geological Survey).

A special class of collaborations is represented by radiocarbon (^{14}C) measurements carried out within the cooperation with Isotopetech Ltd., which were related to dating for archaeological and environmental archaeological purposes, as well as for research in nuclear environment

protection. In the first eight months of the year, more than one thousand individual samples were processed for numerous foreign and Hungarian universities, museums and companies.

Atomki joined the Hungarian Nuclear Fusion Technological Platform as a founding member.

In the commercial sector, MVM Paks Nuclear Power Plant Private Llc. is still the most significant industrial collaborator of Atomki.

Participation in higher education continued to play an important role in the activity of Atomki researchers in 2019 too. This concentrated mainly at the Faculty of Science and Technology of the University of Debrecen. Altogether 17 theoretical and 7 practical courses were held in the spring semester. Atomki hosted 27 PhD, 12 MSc and 3 BSc students in 2015. Altogether 51 Atomki researchers were involved in PhD education, seven of them as ``core members'' of doctoral schools. Five of them belonged to the physics, and two to the informatics doctoral school of the University of Debrecen. The student researcher fellowship program continued in Atomki with the participation of three students in the spring semester.

IV. Brief summary of national and international research proposals, winning between the 1st of January and the 31st of August, 2019

- *Quantum correlations,* 'Momentum' Research group of the Hungarian Academy of Sciences, 2019-24

- *Supplying Accurate Nuclear Data for energy and non-energy Applications – SANDA,* consortial membership in the H2020-Euratom-1.1, ID 847552 project, 48 months, 20 kEUR

- *Research And Development with Ion Beams - Advancing Technology in Europe – RADIATE,* consortial membership in the H2020-EU.1.4.1.2, ID 824096 project, 48 months, 180 kEUR

- *Molecular Dynamics in the GAS phase,* EU COST Action: OC-2018-2-23261, 2019-22, multilateral collaboration

V. List of important publications between the 1st of January and the 31st of August, 2019

Best A ; Pantaleo FR ; Elekes Z; Fülöp Zs; Gyürky Gy; Szücs T; et al. (48)
Cross section of the reaction 18O(p,γ)19F at astrophysical energies: The 90 keV resonance and the direct capture component.
PHYSICS LETTERS B, 797: 134900. (2019)
https://doi.org/10.1016/j.physletb.2019.134900

Bíró B ; David G ; Fenyvesi A ; Haggerty JS ; Molnár J ; Nagy F ; et al. (11)
A comparison of the effects of neutron and gamma radiation in silicon photomultipliers.
IEEE TRANSACTIONS ON NUCLEAR SCIENCE, 66: 1833-1839. (2019)
https://arxiv.org/abs/1809.04594

Boeltzig A; Best A ; Elekes Z; Fülöp Zs; Gyürky Gy; Szücs T; et al. (49)
Direct measurements of low-energy resonance strengths of the 23Na(p,γ)24Mg reaction for astrophysics.
PHYSICS LETTERS B, 795: 122-128. (2019)
https://doi.org/10.1016/j.physletb.2019.05.044

Bruno CG ; Aliotta M ; Elekes Z; Fülöp Zs; Gyürky Gy; Szücs T; et al. (38)
Improved astrophysical rate for the 18O(p,α)15N reaction by underground measurements.
PHYSICS LETTERS B, 790: 237-242. (2019)
https://doi.org/10.1016/j.physletb.2019.01.017

Buga Cs; Hunyadi M ; Gácsi Z ; Hegedűs Cs ; Hakl J ; Csík A et al. (8)
Calcium silicate layer on titanium fabricated by electrospray deposition.
MATERIALS SCIENCE & ENGINEERING C-MATERIALS FOR BIOLOGICAL APPLICATIONS, 98: 401-408. (2019)
http://hdl.handle.net/2437/264202

Cseh, J.
Spontaneous symmetry-breaking in Elliott-type models and the nuclear deformation.
PHYSICS LETTERS B, 793: 59-64 (2019)
https://doi.org/10.1016/j.physletb.2019.04.033

Cseh J ; Riczu G; Darai J.
Shape isomers of light nuclei from the stability and consistency of the SU(3) symmetry.
PHYSICS LETTERS B, 795: 160-164 (2019)
https://doi.org/10.1016/j.physletb.2019.06.016

Csík A; Zayachuk DM ; Slynko VE; Schmidt U; Buga Cs ; Vad K:
Amorphisation effect in binary tellurides under low energy Ar+ ion bombardment.
MATERIALS LETTERS, 236: 5-8. (2019)
http://hdl.handle.net/2437/259070

Csík A ; Shenouda SS ; Erdélyi Z ; Beke D
Dissolution of thin TaV2 during annealing of Ta/TaV2/V tri-layer below the order-disorder temperature.
APPLIED SURFACE SCIENCE, 466: 381-384. (2019)
http://hdl.handle.net/2437/257699

Endrődi G ; Giordano M ; Katz SD ; Kovács TG ; Pittler F
Magnetic catalysis and inverse catalysis for heavy pions.
JOURNAL OF HIGH ENERGY PHYSICS, 2019: 007. (2019)
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