

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

## **I. Main duties of the research unit in 2012**

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

## **II. Remarkable research and other results in 2012**

### **a) Remarkable research**

#### *Quantum Physics*

The interaction of a particle with the surrounding medium is usually described by some potential function  $V(x)$ . It is also often necessary to take into consideration the effects of this medium using a position-dependent effective mass. Inspired by earlier result on the Coulomb potential it was found that the spectrum remains stable if the energy-dependent  $m(x,E)$  mass has negative value only in a limited coordinate and energy domain.

The problem of closing the detection loophole in multipartite Bell tests was investigated, and it was showed that the required detection efficiencies can be significantly lowered compared to the bipartite case. The results are likely to find applications in device-independent quantum key distribution.

In the description of scattering events the correct asymptotic behavior has to be imposed on the wave function. For numerical calculations the methods, which avoid an explicit construction of boundary conditions have a great merit. The complex scaling is such a method. However, for pure Coulomb scattering this method does not work. A new prescription is given, which cures this drawback of the complex scaling for two-body Coulomb scattering.

Anti-bound states as members of the unbound states which can be included into quantum mechanical single-particle bases were studied. It was found that the pole trajectories strongly depend on the tail behavior, where the potential is small but differs from zero. Therefore the construction of anti-bound states requires the use of asymptotically strictly zero potentials.

#### *Particle Physics*

The scientists of Atomki were active participants in achieving the biggest result of CERN in 2012, the observation of a 125 GeV boson. The data collection for the observation of the new boson was done at the two big experiments of LHC (CMS and ATLAS). For the construction and operation of one part of the CMS detector the Debrecen group was responsible. The Atomki scientists participated with 16 online shifts in the data collection. The data obtained so far suggests the identification of the new boson as the Higgs-particle of the Standard Model. The results were published in many articles in 2012 [Phys. Rev. Lett: 12, J. High. En. Phys.: 31, Phys. Rev. D:6 és Phys. Lett. B: 23 publications].

Functional renormalization group (RG) method is suitable to perform renormalization non-perturbatively. However, the approximated RG equations depend on the choice of the regulator function, i.e. on the renormalization scheme. Thus, optimization is required. In the present work, a compactly supported smooth (CSS) regulator function has been constructed, i.e. it has derivatives of all orders and non-zero in a finite range.

They showed that fermion localization, previously found in simplified models, also occurs in the theory of strong interactions (QCD) at high temperature. They determined the temperature dependence of the mobility edge in the quark spectrum and demonstrated that it scales properly with the lattice spacing. Thus the mobility edge is a genuine physical quantity in the continuum limit.

### ***Nuclear Physics***

The shape isomers of the  $^{28}\text{Si}$  nucleus have been predicted based on symmetry considerations. These are largely deformed states of exceptional stability. The theoretical investigation gave also the nuclear reactions, which can populate these states.

Based on the results of the experiments performed at GSI a novel method for measuring the neutron-skin thickness of the atomic nuclei was developed.

The fission probability of  $^{238}\text{U}$  as a function of the gamma-ray energy has been studied at the High Energy gamma Facility (HigS) at the Duke University (USA). The experimental results help to confirm the existence of the third valley of the fission probability.

The scissors mode of giant resonances in  $^{238}\text{Np}$  was studied at the cyclotron laboratory of the Oslo University and the strength function of the resonances was determined

The energy efficiency and nonlinearity of large volume (3"×5")  $\text{LaBr}_3$  detectors was measured up to 18 MeV in a Debrecen experiment in the frame of an Italian-Hungarian collaboration. Gamma-gamma coincidence measurements were performed in Debrecen using state of the art  $\text{LaBr}_3$  gamma spectrometers for studying clusterization effects in light nuclei.

The  $^{56}\text{Ni}(p,p')$  and the  $^{56}\text{Ni}(p,n)$  reactions were studied at GSI using the ESR storage ring. Conclusions were drawn for the distribution of nuclear matter (thickness of neutron skin). The ejected neutrons were detected by the European Low Energy Neutron Spectrometer (ELEN) developed in Atomki.

In nuclear structure studies with radioactive beams the search for new (sub)shell closures is one of the main topics. The properties of the new  $N=16$  shell closure have been studied in the next to neutron drip line nucleus  $^{24}\text{O}$  and the close to proton drip line nucleus  $^{36}\text{Ca}$ .

Exploration of the mechanism leading to the disappearance of classical magic numbers has been performed via the study of the  $N=20$  and  $N=28$  single closed shell nuclei  $^{34}\text{Si}$  and  $^{44}\text{S}$ , as well as the next to  $Z=28$  nuclei  $^{72,74}\text{Zn}$ . In these nuclei, in addition to the spherical shape associated with their semi magic character, states with deformed shapes have also been identified. Lowering of these states originating from cross shell excitations results in the disappearance of the classical magic numbers.

A new topic was started, namely the study of the effective interactions in exotic nuclei. By studying the structure of the neutron rich Pb isotopes it has been shown that in addition to the standard 2-body forces deduced from the free nucleon-nucleon interaction 3-body forces are needed, that is the presence of a third nucleon affects the the nucleon-nucleon interaction.

In the case of alpha-induced reactions it was experimentally proved for the first time that the total cross section obtained from elastic scattering experiments and from the cross section measurements of various reaction channels are the same.

High-spin states of the nucleus  $^{104}\text{Pd}$  were studied via the  $^{96}\text{Zr}(^{13}\text{C},5n)$  reaction at incident energies of 51 and 58 MeV, using the Euroball IV  $\gamma$ -ray spectrometer in conjunction with the DIAMANT charged-particle array. Several new medium- and high-spin bands were revealed. Medium- and high-spin states of  $^{132}\text{La}$  have been studied from  $^{100}\text{Mo}(^{36}\text{S},p3n)$  and  $^{116}\text{Cd}(^{23}\text{Na},\alpha3n)$  fusion-evaporation reactions using the Euroball and the Gammasphere detector arrays, respectively. The level scheme of  $^{132}\text{La}$  has been considerably extended, and unambiguous spin and parity values have been assigned to most of the excited states. The observed similarities between the level structures of  $^{132}\text{La}$  and  $^{134}\text{Pr}$  suggest the possible existence of a band in  $^{132}\text{La}$  that may show chiral features.

With the low energy cross section and high precision measurement of the  $^{17}\text{O}(p,\gamma)^{18}\text{F}$  reaction carried out with two independent methods the accuracy of Nova nucleosynthesis models has been substantially increased.

The reliability of statistical model calculations relevant for the astrophysical p-process has been studied by measuring alpha-induced reaction cross sections on  $^{130,132}\text{Ba}$  and  $^{127}\text{I}$  isotopes and new reaction rate values have been provided.

With detailed background measurements it has been proved that under certain conditions shallow underground laboratories provide a reasonable alternative to deep underground labs for nuclear astrophysics experiments.

Neutrons, necessary for the astrophysical s-process, are released in part by the  $^{13}\text{C}(\alpha,n)^{16}\text{O}$  reaction. The strength of the subthreshold resonance in this reaction was measured using the indirect Trojan Horse technique.

The critical evaluation of the new experimental nuclear-structure data on all the  $A=128$  nuclides has been completed.

New experimental nuclear-structure data on all the  $A=46$  nuclides have been compiled and critically evaluated. As a result of the critical evaluation, adopted values have been suggested for all the considered nuclides.

### ***Applied Nuclear Physics***

Four measurement campaigns were carried out within the CHARISMA EU FP7 project; altogether 6 foreign researchers were received from Belgium, Germany, Poland and Romania. Material from Egyptian quarries, jewellery from the early Iron Age, belt fittings from the Middle Ages and metallic threads from textiles were analysed.

Optical grating and microlenses were made by direct writing with proton and carbon microbeams. The irradiations are finished, presently the devices are under investigation and the scientific conclusions are considered.

A new in-air micro-beam measurement system and data acquisition setup was installed at the Atomki scanning nuclear microprobe beamline which enables the determination of elemental composition with 10-100 micrometer lateral resolution in wide atomic number range ( $Z \geq 3$ ).

Deuteron-induced gamma-ray emission (d-PIGE) cross sections were measured for N and Si in the frame of the IAEA coordinated „Assessment of Nuclear Data Needs for Particle Induced Gamma Ray Emission (PIGE)” program.

New methods were developed for the production of  $^{64}\text{Cu}$  and  $^{203}\text{Pb}$  radioisotopes for animal experiments in developing processes of new drugs. The studies are running in collaboration with SOTE and Technical University, Budapest.

For the radiochemical measurement of difficult to measure beta emitting  $^{79}\text{Se}$  radioisotope, existing in the waste of Paks Nuclear Power Station, new method was developed by the application of  $^{75}\text{Se}$  radioisotope as tracer.

The influence of copper was studied on zirconium dioxide support during catalytic methanol conversion by radioisotope method. The consecutive coverage of the catalyst surface with  $^{11}\text{C}$ - and/or  $^{12}\text{C}$ -methanol gives information about weak and strong catalytic active sites.

In the frame of the study of activation cross sections and production yields of charged particle induced reactions the determination of new experimental data, development of new methodology for application of nuclear data has been carried out.

Cross sections were measured on  $^{67}\text{Zn}$  targets to produce the medically relevant  $^{64}\text{Cu}$  radioisotope. The proton irradiations were performed at the NIRS cyclotron in the  $E_p < 30\text{MeV}$  energy region.  $^{192}\text{Os}$  targets were used to produce the medically relevant  $^{193\text{m}},^{195}\text{Pt}$  radioisotopes.

The relationship between water transport and carbon reallocation processes was studied for trees of different oak species and oak hybrids. For the exceptionally dry growing season of 2012 valuable data were obtained in the research forest area of the Síkfőkút Project of Debrecen University.

Further development was made in the application of isotopes with activity under the Free Handling Limit (FHL). This research is running together with the Austrian AC<sup>2</sup>T institute. The application of new isotopes was introduced for the investigation of parts without the most common basic materials (Fe, Cu, ...).

In the frame of international cooperations measurements were made of cross sections of proton and deuteron induced nuclear reactions on different targets for accelerator technology purposes and thin layer applications.

In the framework of the PHARMATOM project the target systems for the production of  $^{18}\text{F}$  and  $^{11}\text{C}$  radioisotopes were installed. After the synthesis of  $^{11}\text{C}$ -labeled compounds, the chemical synthesis of  $^{18}\text{F}$ -labeled compounds have been started.

### ***Atomic collision processes***

The collisions of  $\text{H}^0$  atoms and protons with noble gas atoms were studied in a set of measurements at the VdG-1 accelerator of Atomki. Information was obtained about the role played by the electron of the  $\text{H}^0$  projectile in the process of the multiple vacancy production induced by the collision.

The collision-induced asymmetry of the charge distribution of the atomic electrons, i.e., the phenomenon of the alignment was studied both experimentally and theoretically. The experiments were done by an Indian group at the pelletron accelerator of the Bhabha Atomic Research Centre using 18-60 MeV fluorine ions. The contribution of Atomki to this work was the completion of theoretical calculations. The new experimental data support the adequacy of the applied model.

The process of the transfer ionization was treated as a special case of double ionization in collisions of He atom with energetic bare ion impact. The calculations reveal good agreement with experimental results. They found that the collision mechanism in which the projectile interacts separately with both electrons gives a realistic account of the process only at low impact energies. At high impact energies the shake off mechanism and the initial state correlations were found to be important.

At the Department of Physics of the University College London the development of a new measuring system was continued. The new apparatus is devoted to determine the energy and angular distribution of the recoil target nucleus in positron-atom collisions.

The charge transfer process was studied theoretically in collisions of  $\text{He}^+$  ions with the NO molecule, which is an interesting molecule both from an atmospheric and biological point of

view. The mechanism of the charge exchange reaction was investigated in detail in connection with the non-adiabatic interactions between the electronic states of the  $\text{HeNO}^+$  quasimolecule. The process was found highly anisotropic: charge transfer cross sections are of the same order in magnitude as the experimental data in the linear approaches but significantly lower in the perpendicular geometry.

Fragmentation of methane, water and nitrogen molecules was measured using  $\text{N}^+$  and  $\text{N}_2^+$  projectiles with the same velocity. Though the fragmentation yield is almost twice as high in the case of molecular nitrogen ion projectiles, a significant and energy-dependent deviation from the constant ratio reflects the geometry of the colliding molecular species. The measurements were carried out at the VdG-5 accelerator in Atomki.

The production of anion fragments was studied in  $\text{OH}^+ + \text{Ar}$  and  $\text{O}^+ + \text{CH}_4$  collision systems using low energy projectiles. After electrostatic analyzing, electrons and anions were separated by a magnetic field. Some of the measurements were repeated using a time-of-flight spectrometer. They observed different anions ( $\text{H}^-$ ,  $\text{O}^-$ ) with significant yields resulting from two- and many-body collisions. The experiments were performed in the framework of an international (TÉT) collaboration at GANIL, France.

The time-evolution of the plasma in the ECR ion source was studied in pulsed operation mode during the preglow and afterglow using a 1000 frame/s fast camera. The studying of the transient states gave valuable information on the mode and place of the highly charged ions. The computer simulation of the ECR plasma was continued by following the energy and spatial evolution of very large number (3 million) of electrons. The energy filtering of the remained electrons revealed interesting and important information in 3D.

Functionalization of material surfaces was carried out by ion beams for different kind of technical and biological purposes. By the request of an American partner in collaboration with the University of Debrecen chalcogenide samples were irradiated by  $\text{Ar}^{8+}$  ion beam in order to produce nano-switches. Structural modification of titanium surfaces on nano scale was carried out by  $\text{Au}^{9+}$  ion beam motivated by the creation of metal nanoparticle. Biologically important zirconium samples were irradiated by  $\text{Si}^{3+}$  ion beam to improve the lifetime and mechanical stability of the dental implants.

The angular distribution of Kr 4p photoelectrons was measured in wide photon energy range ( $h\nu=60-120$  eV) at the DORIS III synchrotron in Hamburg. The aim of the study was the observation of octopole interaction in photon-atom collision and the investigation of its energy dependence.

In cooperation with scientists of Justus-Liebig University (Giessen, Germany) a photon-ion-spectrometer was installed at the Petra III synchrotron in Hamburg. Approximately 100% overlap was reached between the ion and photon beams in the merged beam region of the spectrometer.

A special time of flight spectrometer (TOF) was developed physically, mechanically and was built to the pre experiments of the ELI ALPS system. The designed electron optics can transport the electrons to the detector from  $\pm 10^\circ$  cone angle with 44 psec time spread in case of 1 m flight distance.

Experiments were performed at the ECR ion source to study the guided ion transmission through insulating nanocapillaries. Low energy, highly charged argon and neon beams were shot through nano-capillary arrays. The depletion of the deposited charges of the incident beam was studied, which is responsible for the ion guiding. The first results indicate that the charge depletion is governed by a non-linear-characteristic conductivity. The ion guiding ability of capillaries in multilayered metal-insulator structures was also investigated, and it was found to be very efficient when voltages were applied to the layers.

### *Applications in Atomic Physics, Solid State Physics, Surface Sciences*

Graphene oxide was prepared from graphene flakes by oxidation in ozone and electron plasma. Chemical characterisation of the atomic composition and the content of C hybridisation were performed using XPS, whereas REELS was used for structural characterisation.

XPS and REELS spectroscopy of permanent adult and children's deciduous teeth was performed. Collective excitations in Ca compounds were found. Using the standard phosphoric acid treatment as dentist use, the giant resonance disappeared. The difference corresponds to inorganic components. Giant resonances were found in modern tooth fillings used in dentistry.

Surface and bulk sensitive analyses of mouse bone samples were performed to determine their major and trace element components including the corresponding concentration depth profiles. It was shown that XPS is a valuable tool not only for determining the chemical states of the major components atoms of the bone powder but for quantitative determination of their relative concentrations as well. Concentrations of the major and the trace elements of the bone samples were determined from the analysis of PIXE and SNMS spectra of the samples too.

According to their novel observations, electron energy losses and associated deflections in vacuum above the surface of solids (super-surface electron scattering), contribute significantly to electron spectra. Theoretical calculations using accurate Monte Carlo simulation show that super-surface scattering is an essential phenomenon for quantitative understanding of electron spectra.

Dirac-Fock-Slater atomic calculations were performed for interpreting the excitation mechanism of the satellite peaks observed in the 1s photoelectron spectra of 3d transition metals excited by synchrotron radiation from 3d transition metals. Among the two models (3d  $\rightarrow$  4d shake-up excitation following the photoionization, or a 3d  $\rightarrow$  4s transition due to the partial overlap of the valence bands) the latter one gives a better agreement with the experimentally determined values of the energy separations between the main lines and the satellite peaks.

Guiding of highly charged ions through tilted capillaries promises to develop into a tool to efficiently collimate and focus low-energy ion beams to sub-micrometer spot size. One control parameter to optimize guiding is the residual electrical conductivity of the insulating material. Its strong, nearly exponential temperature dependence may help to control transmission and to suppress transmission instabilities arising from flux fluctuations of incident ions.

Investigations of guiding of few hundred eV antiparticles by macroscopic insulating capillaries have been started. By using sub-femtoamp positron and electron beams it was demonstrated that a portion of the entering beams were transmitted and emerged in the direction of the capillary. The transmitted intensities decreased as the capillary tilt angle was increased.

A joint experimental and theoretical study was made on electron transmission through Al<sub>2</sub>O<sub>3</sub> capillaries. The microscopic electron-transport simulation includes interaction processes at the surface and in the target material. It was found that charging-up is no longer a necessary precursor for transmission. Furthermore, while charging-up influences the trajectories it can lead also to attraction rather than repulsion.

The time dependent behaviour of a 1 MeV proton microbeam passing through a polytetrafluoroethylene single microcapillary was investigated. The energy distribution of the transmitted protons was also analysed. Three completely different regions were identified in the transmission as a function of time.

Transparent conductive oxide thin films prepared by chemical vapor deposition were studied using a depth profile analysis method developed recently. This method is particularly suitable to study the depth homogeneity of elements. The homogeneity can be improved by annealing the sample in air at a given temperature for a short time.

Barkhausen noise in soft magnetic materials was studied at low temperatures, in the frame of a scientific cooperation. While measurement of the Barkhausen noise at room temperature is a common procedure, it seems to be a new idea to study it at very low temperatures. It is also a new possibility to measure the effect of a laser beam on chalcogenide samples at low temperatures. Since the sample temperature is low, thermal excitation can be neglected. This way a laser beam induced structural change can be studied without thermal atomic motion.

Multilayer films produced by magnetron sputtering were studied using XRD method. Phase analysis of inorganic compounds using X-ray powder diffractometry and XRF analysis of archaeological objects from the collections of Hungarian museums were also carried out.

Methods were developed for electrical, optical and nuclear characterization of single SiAPD microcells, SiPM units and matrices („tiles”) of SiPM sensors. The methods were used for the qualification of pilot devices under development. Examinations deliver information on the details of the basic physical processes underneath by testing single cells, and on optical crosstalk and response nonlinearity for full SiPM units. As for SiPM tiles, besides response homogeneity tests, the final goal was the determination of the optimal thickness of an integrated light sharing optical guide.

GSO and LYSO nano-scintillators were constructed. The size distributions were determined with XRD and the energy transfer mechanism was studied by the REELS method.

Special light guides for low noise readout of large area triangular shaped CsI(Tl) scintillation detectors with small size square shaped silicon photodiodes were constructed for nuclear research studies.

### ***Environmental Physics***

In the field of K-Ar chronology, geological field works were performed in the Eastern- and Western Carpathians within the frame of Slovakian-Hungarian and Romanian-Hungarian co-operations. Moreover, K-Ar data obtained on Cenozoic magmatic rocks from King George Island, Antarctica, were evaluated within a Polish-Hungarian project.

Chronology of plutonic and effusive rock of the Bohemian Massif was studied and a review was made on recognized possible errors of K – Ar ages on young basaltic rocks; methods for the correction of the errors were elaborated. Changes of formal K – Ar ages on clay minerals from soils, as an effect of fertilization and vegetation were analysed.

New methods have been developed and implemented in AMS of Hertelendi Laboratory of Environmental Studies for C-14 analyses of dissolved organic compounds of groundwater as well as canvas of fine art products. A novel method was used to estimate the construction date of Zsolca Mounts.

The stable isotope signature ( $\delta^{13}\text{C}$ ,  $\delta^{18}\text{O}$ ) of a stalagmite from the Hajnóczy Cave was determined. Determination of tritium concentrations of monthly precipitation samples from the past 11 years was also done. Comparative analysis of the tritium concentrations and the 11-year solar cycle was made. Different methods to extract and purify alpha-cellulose from tree ring samples were refined.

By measuring the radon emanation rate of soil samples instead of in situ radon concentration of soil gas they have redefined the procedure to determine radon source potential of building

sites. This development resulted in a more reliable and more cost-effective procedure. In a representative survey they have identified a radon prone area in a Transylvanian village.

A novel method has been developed to investigate the C-14 contamination in dissolved organic forms of monitoring groundwater well samples in the vicinity of a radioactive waste repository site (Püspökszilágy, Hungary).

An overall study started to measure the C-14 level in the different media (primary circuit, cooling pond and spent fuel transferring C-30 container) of the water system of Paks Nuclear Power Plant. A novel calibration method for the inhermetic fuel detector system (SIPPING) of the Power Plant was developed. Other developments in the Power Plant are: refining the Se-79 analyses technique by enhancement of the radio-chemical preparation and its ICP-MS controlling protocol, development of a novel method for direct LSC C-14 analyses of stack air exposed base solvents from nuclear facility to simplify atmospheric C-14 release monitoring.

Chemical speciation of Cl and S in atmospheric aerosol samples were performed by high-resolution wavelength dispersive proton induced X-ray emission (PIXE) spectroscopy at the Jozef Stefan Institute in Ljubljana, Slovenia. The  $K\alpha$  spectra which refer to the oxidation state, showed very minor differences due to the high electronegativity of Cl. However, the  $K\beta$  spectra exhibited pronounced chemical effects which were significant enough to perform chemical speciation. The results confirmed the potential of high-resolution PIXE method for the chemical speciation of chlorine on thin, lightly loaded aerosol samples collected on filters, without any sample preparation in a nondestructive way. They determined that the chemical form of S was sulphate ( $SO_4$ ) in the winter aerosol samples.

Workplace aerosol pollution was studied in the form of case studies. A complex study of workplace aerosols was presented, in which the composition, size distribution, sources, formation processes and lung deposition probabilities of indoor particulate matter were determined in a working hall where wave soldering takes place. As a result, outdoor and indoor aerosol sources such as wave soldering, fluxing processes, workers' activity, mineral dust, biomass burning, fertilizing and other anthropogenic sources could be separated.

## **b) Dialog between science and society**

From the rich connections between physics and everyday life, in 2012 the field of engineering was selected to be in the focus of the „Physicists' Days”, Atomki's traditional, annual outreach event for non-professionals. In the lectures, students and other participants could meet many spectacular results that emerge from the interaction of physics and engineering sciences. Programs with 'open day' character were also organized, where participants visited selected interesting laboratories of the Insitute. Including high school student visitors of the 'extraordinary physics lessons', the number of participants was around 1000, which can be considered as a high attendance.

Besides Physicists' Days, there were also some other opportunities offered for the open public to visit Atomki during the year. Usually a group of students visited a laboratory of the Insitute this way and listened a researcher's lecture on a preorganized basis.

In March, a Museum of Atomic Energy was opened at the location of Paks Nuclear Power Plant, which is unique in Europe. Several exhibited instruments of the newly opened museum had been donated by Atomki.

The May issue of the popular-scientific journal 'Természet Világa' ('World of Nature') presents several articles that are authored by Atomki researchers, describing their research works in spotlight. The issue has a DVD attachment containing a documentary-entertaining movie 'Elemi álom' (Lab Love), with animated microparticles as cartoon figures, giving an insight to their world as well as the research work at a few departments of Atomki.

One of the accelerators of the Institute – namely the ECR ion-source – has come to its 20th year of operation. For this occasion a scientific meeting was organized with scientific and popular lectures, which was an important part of the outreach activity in September of 2012.

Still in September, another traditionally successful event was enjoyed by the public audience. This was the „Researchers’ Night”, a part of the EU-wide outreach programme. A talk about nanosystems was presented in the overcrowded lecture hall of Atomki, and student visitors played until the night with special experimental tools collected for this event.

The Large Hadron Collider of CERN was in the focal point of the world's scientific life in 2012 due to the crucial experiments performed there in searching for the Higgs-boson. Atomki also took part in the popularization of this heroic episode of particle physics. Within the framework of the Hungarian Science Feast in November, a public symposium was devoted to the new grid in the computer center of the institute, which serves the data handling of the experiments at the Large Hadron Collider. During the year another talk about the Higgs-boson filled the lecture hall too.

Beyond their articles and lectures, the researchers of the Institute showed up on other forums too, like in interviews at the homepage of OTKA, and in the journals *Élet és Tudomány* (Life and Science) and *Innotéka*. They used these opportunities to give a flavor of their research work and talk about their view of science. Several news turned up about the Institute in local and national newspapers and internet forums.

### **III. National and international relations in 2012**

The most important national partners in scientific collaboration are the University of Debrecen and the Wigner Physics Research Center, but there are numerous cooperations with other institutes in the country as well.

Radioactive monitoring and controlling of the nuclear energy related instrumentation at Paks, Püspökszilág and Bataapati is an important activity of Atomki, for the national system of the environment protection.

Radiocarbon age-determination services of Atomki significantly contribute to the correct work of different national and foreign institutes, organizations, corporations and individuals.

The Isotoptech – MTA ATOMKI – ETH trilateral Swiss-Hungarian research agreement – „*Development of an EnvironMICADAS <sup>14</sup>C AMS system for Hungary*” has been successfully completed in 2012.

In 2012, the Institute preserved its positions in the higher education, and strengthened its traditional links with the University of Debrecen (DE). In addition, Atomki researchers delivered lectures at the University of Szeged and at the University of Pécs. In the reported period of 2012, Atomki researchers held 860 lessons in the framework of 45 courses at DE. The number of the practical classes were 226 within 27 courses at DE. Overall 34 researchers were involved in higher education activities. Besides the involvement in undergraduate teaching, the Institute has a remarkable educational activity in doctoral schools. Nine of the 20 principal members of the Physics Doctoral School at the University of Debrecen are Atomki researchers. During the reported period, 19 graduate students, 11 MSc undergraduates, 6 BSc undergraduates and 7 research students worked in the Institute, and 3720 hours were spent on supervising them. The granting system of Researcher Student scholarship, in which the university students participate in the research work, continued in the Institute. Eight students enrolled in the spring, and six in the autumn semester. The Institute also hosted physics undergraduate (Bsc) students as trainees from the University of Debrecen for a 6 day course.

The researchers of the Institute organized and participated the XV. Nuclear Physics Meeting at Jávorkút.

International relations substantially contributed to the research activity of the Institute in this period as well. Many ongoing cooperations continued and Atomki hosted several international meetings.

Atomki researchers successfully organized the ‘10th International Conference on Clustering Aspects of Nuclear Structure and Reactions’, which was held between the 24th and 28th of September. 87 foreign and 20 Hungarian researchers attended the large meeting, where more than 80 oral presentations were delivered. The site of the event was the Kölcsey Conference Center in Debrecen. Participants also visited Atomki, where program was organized for them. In addition, the main lecturer of the Researchers’ Night had been selected from the participants of this conference. Lectures that were presented at the conference will be published in a 2013 issue of the Journal of Physics Conference Series. Both the participants and the International Advisory Board evaluated the conference as a success.

An aerosol-analysis training was organized by the Department of Ion-Beam-Analytics of the Institute as a part of the education programs of the International Atomic Energy Agency (IAEA), attracting participants from the Middle-East and local professionals.

The ECR Laboratory hosted a two-days professional symposium (ENSAR program, ARES sub-program), where German, French, Italian, Dutch, Finnish and Hungarian researchers consulted about the ECR ion beam related researches.

Atomki was an active member in the ENIAC's (European Nanoelectronics Initiative Advisory Council) Sub-Program for the Improvement of Small-animal-PET Technology. It was also Atomki, the leader of the Hungarian consortium that hosted the ENIAC CSI Project Meeting in September.

A number of foreign researchers came to visit Atomki for longer periods of time (minimum a few months) in 2012. A researcher in nuclear astrophysics from Bucharest spent 8 months within a 2-year National Research Fund (OTKA) grant. Another researcher from Turkey worked on his PhD thesis in the same field by the help of an Erasmus scholarship. A Fulbright scholar professor arrived from the University of Arizona to work on a C14-dating topic as guest-researcher for 5 months. The Hungarian Academy of Sciences (MTA) invited a theoretical nuclear physicist – working in nuclear astrophysics – who spent 4 months in the Institute.

The transnational access project CHARISMA, an EU FP7 program continues to play an important role in foreign researchers’ activity in Atomki. Saving the cultural heritage is a priority in the European Union. In 2012, within the framework of the above project, 6 foreign researchers were hosted by the Institute from Belgium, Poland, Germany and Romania.

The external advisory board of Atomki held its annual meeting in the Institute on 24-25th of September, 2012.

#### **IV. Brief summary of the most important 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 Hungarian National Research Foundation (OTKA and NKTH-OTKA), while the highest international funding came from the organizations of the European Union.

In 2012, the Institute had 112 tenders and scientific grants, 42 of which was worth above 10 MFts and 25 was worth above 20 MFts. These latter 25 applications will be listed below, indicating the amounts actually transferred to Atomki, and their proportion for the year 2012.

It is to be mentioned here that the Institute is consortial member for several successful TÁMOP applications. Three of these belong to the University of Debrecen, one to the University of Szeged and one to the University of Miskolc. Although the majority of these projects starts in 2013, obtaining them is a success of the year 2012.

NDA: Complex development in building energetics, 325959 eFt – 198335 eFt  
NDA: PRIZMATECH cluster, 21845 eFt – 2568 eFt  
NDA: Application of pulsed lasers, 19144 eFt – 4786 eFt  
NDA: Future Internet Research, 49988 eFt  
NDA: Dissemination of the results of Atomki, 99190 eFt  
NDA: Special fundamental research topics in biology and chemistry, 57600 eFt  
NDA: Intelligent functional materials, 116699 eFt  
NDA: Communication protocols, 43172 eFt – 10600 eFt  
NDA: Advanced imaging system, 160954 eFt – 13102 eFt  
NKTH– OTKA: Search for new physics with the CMS detector, 29344 eFt – 3021 eFt  
NKTH– OTKA: The  $3\text{He} + 4\text{He}$  reaction in the Sun, 24000 eFt – 2762 eFt  
NKTH: New generation, environmentally friendly thin-film solar cells, 32000 eFt  
OTKA: Fundamental interactions and exotic nuclear states, 23157 eFt  
OTKA: synthesis of nucleons of heavy elements, 21998 eFt – 6941 eFt  
OTKA: Correlations in the atomic nucleus, 31008 eFt – 13152 eFt  
OTKA: Development of neutron detectors, 29985 eFt – 21588 eFt  
Radioactive Waste Dep. Ltd.: Püspöksz. RHT area. Samples exam., 108788 eFt – 28096 eFt  
EU: The future's laboratory of materials science, 105723 EUR – 25723 EUR  
EU: Development of artificial diamond-based detectors, 34202 EUR  
EU: Development of E+ E- detectors, 59625 EUR  
EU: EURATOM Fusion Training, 145350 EUR  
EU: Tritium education program, 65000 EUR  
EU: Collective excitations in atomic ionization, 100000 EUR  
EU: Astrophysical p-process, 750000 EUR  
EU: CHARISMA, 197000 EUR – 102501 EUR

**note: eFt means 1000 Hungarian Forint**

## V. List of important publications in 2012<sup>1</sup>

1. Chatrchyan S, Khachatryan V, Sirunyan AM, Tumasyan A, Adam W, Aguilo E, et al. (2891) Horváth D, Béni N, Fenyvesi A, Molnár J, Pálinkás J, Szillási Z: Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC. Physics Letters B, 716:(1) 30-61 (2012)
2. La Cognata M, Spitaleri C, Trippella O, Kiss GG, Rogachev GV, Mukhamedzhanov AM et al. (15): Measurement of the - 3 keV Resonance in the Reaction C-13(alpha, n)O-16 of Importance in the s-Process. Physical Review Letters, 109:(23) Paper 232701. 5 (2012)
3. Csige L, Csatlós M, Faestermann T, Gulyás J, Habs D, Hertzenberger R et al. (11) Hunyadi M, Krasznahorkay A: Transmission resonance spectroscopy in the third minimum of Pa-232. Physical Review C Nuclear Physics, 85:(5) Paper 054306. 5 (2012)
4. Gottardo A, Valiente-Dobón JJ, Benzoni G, Nicolini R, Gadea A, Lunardi S et al. (84) Algora A, Dombradi Z: New isomers in the full seniority scheme of neutron-rich lead isotopes: The role of effective three-body forces. Physical Review Letters, 109:(16) Paper 162502 (2012)
5. Gruber E, Kowarik G, Ladinig F, Waclawek JP, Schrempf D, Aumayr F et al. (12) Berezky RJ, Tókési K: Temperature control of ion guiding through insulating capillaries. Physical Review A, 86:(6) Paper 062901. 8 (2012)
6. Gulyás L, Igarashi A, Kirchner T: Double and transfer ionization in collisions of He with bare ions. Physical Review A, 86:(2) Paper 024701 (2012)
7. Gyürky Gy, Mohr P, Fülöp Zs, Halász Z, Kiss G G, Szücs T, Somorjai E: Relation between total cross sections from elastic scattering and  $\alpha$ -induced reactions: The example of <sup>64</sup>Zn. Physical Review C Nuclear Physics, 86:(4) Paper 041601. 6 (2012)
8. Juhász Z, Kovács S T S, Herczku P, Rácz R, Biri S, Rajta I et al. (10) Szilasi S Z, Pálinkás J, Sulik B: Guided transmission of 3 keV Ar<sup>7+</sup> ions through dense polycarbonate nanocapillary arrays: Blocking effect and time dependence of the transmitted neutrals. Nuclear Instruments & Methods in Physics Research Section B-Beam Interactions with Materials and Atoms, 279: 177-181 (2012)
9. Lévai G: Gradual spontaneous breakdown of PI symmetry in a solvable potential. Journal of Physics A-Mathematical and Theoretical, 45:(44) Paper 444020 (2012)

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<sup>1</sup> Here the main aim is to display important topics. Results considered as significant are shown, even if published in lower IF journals. At the same time, only one is listed here from the numerous high IF papers of the CMS collaboration in 2012 [12 PRL, 31 J. HEP, 6 Phys. Rev. D és 23 Phys. Lett. B].

10. Nándori I, Rácz J: Magnetic particle hyperthermia: Power losses under circularly polarized field in anisotropic nanoparticles. *Physical Review E - Statistical, Nonlinear and Soft Matter Physics*, 86:(6) Paper 061404. 8 (2012)
  
11. Papp L, Palcsu L, Major Z, Rinyu L, Tóth I: A mass spectrometric line for tritium analysis of water and noble gas measurements from different water amounts in the range of microlitres and millilitres. *Isotopes in Environmental and Health Studies*, 48:(4) 494-511 (2012)
  
12. Papp T: A critical analysis of the experimental L-shell Coster-Kronig and fluorescence yields data. *X-Ray Spectrometry*, 41:(3) 128-132 (2012)
  
13. Rotaru F, Negoita F, Grévy S, Mrazek J, Lukyanov S, Nowacki F et al. (22) Dombrádi Z, Sohler D: Unveiling the intruder deformed 2+ state in Si34. *Physical Review Letters*, 109:(9) Paper 092503 (2012)
  
14. Scott D A, Caciolli A, Di Leva A, Formicola A, Aliotta M, Anders M, et al. (32) Elekes Z, Fülöp Zs, Gyürky Gy, Somorjai E, Szücs T: First Direct Measurement of the  $^{170}\text{O}(p,\gamma)^{18}\text{F}$  Reaction Cross Section at Gamow Energies for Classical Novae. *Physical Review Letters*, 109:(20) 202501 (2012)
  
15. Sohler D, Kuti I, Timár J, Joshi P, Molnár J, Paul E S et al. (30) Algora A, Dombrádi Zs, Gál J, Kalinka G, Krasznahorkay A, Zolnai L: High-spin structure of  $^{104}\text{Pd}$ . *Physical Review C Nuclear Physics*, 85:(4) p. 044303. 13 (2012)
  
16. Szoboszlai Z, Kertész Zs, Szikszai Z, Angyal A, Furu E, Török Zs et al. (8) Kiss Á Z: Identification and chemical characterization of particulate matter from wave soldering processes at a printed circuit board manufacturing company. *Journal of Hazardous Materials*, 203-204: 308-316 (2012)
  
17. Szücs T, Bemmerer D, Cowan T, Degering D, Elekes Z, Fülöp Zs, et al. (13) Gyürky Gy: Shallow-underground accelerator sites for nuclear astrophysics: Is the background low enough? *European Physical Journal A*, 48:(1) Paper 8. 8 (2012)
  
18. Tárkányi F, Ditrói F, Hermanne A, Takács S, Ignatyuk A V: Investigation of activation cross-sections of proton induced nuclear reactions on natMo up to 40 MeV: New data and evaluation. *Nuclear Instruments & Methods in Physics Research Section B-Beam Interactions With Materials and Atoms*, 280: 45-73 (2012)
  
19. Vértesi T, Brunner N: Quantum Nonlocality Does Not Imply Entanglement Distillability. *Physical Review Letters*, 108:(3) Paper 030403. 4 (2012)