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I. Main tasks of the research institute in 2009

According to the tasks desrcibed in the deed of foundation as well as those assigned by the Hungarian Academy of Sciences the Research Institute for Particle and Nuclear Physics (RMKI) has conducted successful experimental and theoretical basic research in the field of particle physics, nuclear physics, plasmaphysics, the physics of cool atoms, space physics, nuclear solid state physics, nuclear material science as well as biological applications of physics. The main fields of developments were: laser physics, nuclear analytics, fusion plasma diagnostics, space technology, fast data processing, spectroscopy, special instruments for electronics, mechanics and information technology inculding softwares for various operating systems. As the leading institution of the Hungarian Euratom Fusion Society RMKI coordinated the Hungarian R+D activity in controlled fusion energy production research. It has also improved and operated the EG-2R electrostatic accelerator together with the NIK Heavy Ion Implanter facility, the MBE Molecular Beam Epitaxy device as well as the GRID system and other high power computer networks. It has developed and operated the computer network of the KFKI Campus and serves as the regional center of the National Information and Infrastructure Development Program.

II. Outstanding research and other results, and their socio-economic impact in 2009

High-energy experimental particle and heavy ion physics

The Large Hadron Collider (LHC) of CERN was successfully restarted in November 2009 after various technical problems have been solved. The collision energy (2.36 TeV) achieved in this short period was already higher than the highest energy ever reached before. Intensive work was accomplished even before the start of LHC, the development and the calibration of the detector elements were finished by the use of cosmic radiation.

The Hungarian CMS group (comprising researchers and graduate students from RMKI, ATOMKI, the Institute of Experimental Physics of the University of Debrecen and the Department of Atomic Physics of Roland Eötvös University, Budapest) coordinated by RMKI made a significant contribution to the development of the CMS hardware by installing and operating of the position monitoring system of the barrel muon detector. The Hungarian group had played a significant role in its construction. The system passed all tests in the 4 Tesla field of CMS during the cosmic studies and also with LHC in operation.

The researchers of RMKI took a major part in the first and so far unique energy analysis of proton-proton collisions by evaluating tracks recorded with pixel and strip silicon detectors, determining the pseudo-rapidity and transverse momentum spectra of charged hadrons created in 900 GeV and 2.36 TeV center-of-mass energy interactions. The results show a good agreement with earlier data on proton-antiproton collisions, that also confirms the charge independence of the interaction. The work of our researchers in the large collaboration was widely acknowledged, consequently they actively took part in writing up the publication.

In the frame of the international collaboration RD51 at CERN with the aim to develop different gas detectors in 2009 a new activity has started funded by the consortial OTKA-NKTH grant received by ELTE and RMKI. The work has lead to significant results already during the first year. A prototype of a trigger-detector for the ALICE experiment at CERN-LHC has been developed and succesfully tested in the measurements.

In the CERN LHC ALICE collaboration RMKI scientists – together with Italian and Mexican colleagues – have prepared the Letter of Intent of the „Very High Momentum Particle Identification Detector" (VHMPID), which was accepted by the ALICE Management Board. A small scale test version of the planned HPTD trigger unit was built in the Detector Laboratory of the RMKI, and has been tested in 2009 by 7 GeV protons at CERN. After the analysis of data, the test detector has been rebuilt, a new read-out electronics has been developed. The already constructed and commissioned ALICE High Momentum Particle Identification Detector (HMPID) has started to collect data at LHC and successful data acquisition has been accomplished with active RMKI participation in proton-proton collisions at 900 GeV and 2.36 TeV center of mass energies.

In the CERN LHC TOTEM collaboration (CERN, Geneva) RMKI researchers contributed to the development of the Detector Control System (DCS), which was essential to perform data acquisition during the physical run of LHC in proton-proton collisions at 900 GeV and 2.36 TeV center of mass energies.

Parallel with the high priority LHC experiments the CERN managment strongly supports some selected particle physics experiments at the lower energy SPS accelerator. One of the three supported SPS experiments is the Hungarian-Polish initiated NA61/SHINE project where the Hungarian part was lead by RMKI. It is important to note that the complete hardware and software upgrade of the data acquisition system (DAQ) of the previous NA49 setup was designed and manufactured in Hungary. After the installation of the new DAQ the systematic data collection was started at different energies with proton and pion beams on carbon and liquid hydrogen targets. The first reference measurements were performed in the 20-160 GeV energy range on the p+p system. During the 4 months long measuring period 40 million events were recorded which equals in numbers the total data amount collected during the 10 years life of the previous NA49 experiment, indicating the effectiveness of the upgrade provided by RMKI. The data collected in 2009 are mainly used for the T2K neutrino and Auger, KASCADE cosmic ray experiments. For the further hardware upgrade of the NA61/SHINE experiment the test version of a new centrality detector was tested.

The Detector Data Link (DDL) network cards developed by the Detector Building Group has been successfully used in the Data Acquisition System (DAQ) of both the ALICE and NA61 (SHINE) experiments. For the ALICE DAQ the Detector Building Group developed a new version of RORC (Read-out Receiver Card) working on the base of the PCI Express standard. New techniques employed for filtering out the electronic noises significantly contributed to the success of the NA61 experiment's measurement period in 2009.

At the Antiproton Decelerator of CERN the Tokyo-Budapest-Vienna-Brescia-München collaboration continued the experimental verification of CPT invariance stating the equivalence of matter and antimatter. They have measured the hyperfine splitting of antiprotonic states in antiprotonic helium atoms using a laser-microwave-laser triple resonance method and increased the precision of the determination of the magnetic moment of the antiproton as compared to that of the proton. The collaboration developed the Doppler-free measurement of the transition energies of antiprotonic helium atoms using two oppositely

propagating laser beams. Thus far all measurements confirm the CPT invariance. A detector system for the two-tone Paul trap with significant RMKI participation was designed and built in order to monitor antiproton annihilations after antihidrogen formation.

Within the framework of the Worldwide LHC Computing Grid collaboration the BUDAPEST grid site of RMKI was developed and by the end of 2009 it comprised 426 processors and 144 terabyte disk storage. During 2009 the BUDAPEST site operated with an availability and accessibility above 96 % and proved to be one of the most efficient one among the near hundred LHC Tier-2 sites.

The modification of the mass of eta'(958) meson has been investigated in heavy ion collisions, especially in Au+Au at 200 AGeV center of mass energy. The theoretical analysis was based on PHENIX and STAR data, collected at the RHIC accelerator (Brookhaven, USA). The analysis of correlation functions displayed (with 99.9 % confidence level) a 200 MeV decrease in the mass of eta'(958). This result indicates the partial restoration of $U_A(1)$ symmetry in heavy ion collisions.

Materials science by nuclear methods

In the past year the Materials Science (MS) division of RMKI conducted experimental basic research in the field of materials science primarily by using and developing the available nuclear solid state methods and the related theories. The teams of the division have been operating the EG-2R 5-MeV ion accelerator, the NIK heavy ion implanter and the molecular beam epitaxy (MBE) laboratory, now all featured in the frame of the Hungarian Ion-Beam Physics Platform (HIPP).

Some 98 samples have been prepared by the MBE lab in 48 film depositions for the needs of academic and university research centres in this country as well as in Germany and Russia. The MBE lab has been upgraded with a molecular oxygen source. GINA, the new neutron reflectometer built recently by the MS division has been put to test operation in the Budapest Neutron Center (BNC) and became included into the user scheme of BNC allowing access to external researchers, too.

Beyond the available national facilities, researchers of the MS division were using large European research infrastructures on beam time application and on cooperation grounds alike.

The researchers of the MS division- through their Mössbauer spectroscopic studies of magnetic thin films with great potential in magnetic recording and spintronics- determined the magnetic anisotropy in MgO(100)/Fe/MgO(100) multilayers as a function of the Fe layer thickness. In similar studies carried out for better understanding of processes of layer formation and promoting applications of the Fe_xPd and Fe_xPt systems, in addition to the magnetic anisotropy the phase composition was also determined.

In the resonant inelastic X-ray scattering studies, they gained element-selective insight into the density of the lowest-lying unfilled electronic states the detailed knowledge of which is indispensible for the understanding of the transport and excitation characteristics of transition metal compounds. On the basis of the results a general procedure was proposed for the analysis of 1s absorption pre-edges. The RMKI researchers utilized X-ray emission spectroscopy for the first time to study ultrafast processes: the spin state of a transient of an iron complex was determined 60 ps after the optical pumping.

In the studies of the accumulation of implanted helium in low-lithium-oxide-content $(LiO)_x(SiO_2)_{(1-x)}$ ($x < 0,33$) silicates it was observed that, like from pure silicon oxide, the helium escaped, however, a considerable fraction of helium was retained within the higher lithium oxide content ($x > 0,5$) targets. These results have importance in designing future fusion reactors.

Using polarized neutron reflectometry combined with the resonance enhancement of the neutron intensity in waveguide layer strtructure, for the first time, the reverse effect of the superconducting (SC) state upon the magnetic structure of the ferromagnetic (FM) layer in SC/FM bilayers were observed. The researchers of RMKI developed a piecewise constant diffusion coefficient model for inhomogeneous media and applied this model to FePd alloys. Evaluating experimental neutron and Mössbauer (conversion electron spectroscopy and reflectometry) data they were able to extract three local diffusion coefficients in epitaxial FePd films. After successful theoretical predictions of the reciprocity violation in the nuclear resonance forward scattering of synchrotron radiation and a verifying experiment to their theory was suggested. An effective computer code based on their recent DWBA theory of diffuse Mössbauer reflectometry was proposed, by the application of which they found the domain correlation function in an antiferromagnetic multilayer of exponential shape. They developed a theory and applied the corresponding computer code to simulate the polarization dependent relative intensities of conversion electron Mössbauer spectra, which made possible the determination of the layer magnetizations by Mössbauer polarimetry with an uncertainty as low as a few degrees.

In positron annihilation studies on carbon nanotubes, they assigned the reduced Ps-formation observed as compared to porous materials to the presence of homogeneous clean surfaces. Investigating the formation dynamics of energetic heavy-ion-irradiation-induced structural imperfections in high-purity Si, they found that the formation of divacancies occurs above a trigger dose while polyvancies are formed only above a higher subsequent trigger level. In addition to positron lifetime measurements, they applied Doppler spectroscopy and demonstrated that, with appropriate selection of sample-specific energy windows, the measurement sensitivity could be doubled.

A mobile X-ray fluorescence spectrometer based on Amptek units and featuring a mini X-ray tube has been constructed and has been optimized by establishing the best combination of filter layers positioned before the exciting X-ray and/or the detector, resulting so in the highest element-sensitivity. The results obtained were compared to data collected with an identical spectrometer but operating with radioisotopes (this set-up was also displayed on the Amptek company website as a good illustration of the applicability of such assemblies for the analyzis of art objects) and it was concluded that the sensitivity of the instrument with X-ray tube excitation surpasses about one order of magnitude that of the radioisotope-based one but for the revealing of elements Z>18 instead of the Cu filters Ti filters are more advantageous. It is a well-founded hope now that such X-ray tube based spectrometers can be used extensively in field applications in museums and in art collections collections where up till now *in situ* applications posed serious difficulties of damaging the art objects.

Theoretical physics

Maldacena's famous AdS/CFT (string theory on anti de Sitter space-time/conformal field theory) conjecture states that the conformally invariant N=4 super Yang-Mills theory should be equivalent to the type II-B string theory defined on the 10 dimensional AdS_5xS_5 space-time

such that the anomalous dimensions of the Yang-Mills theory correspond to string energies. The conjecture can be proven only by non-perturbative techniques offered by integrability discovered on both sides of the conjecture. The Konishi operator proved to be of basic importance in testing the conjecture, as this is the simplest operator in the super Yang-Mills theory with non-trivial anomalous dimension. Using the integrability of the string theory and the duality conjecture our researchers computed the anomalous dimension of the Konishi operator up to 5-loops. The result is of particular importance in testing the so-called thermodymamic Bethe Ansatz integral equations proposed to describe the exact spectrum of string energies/anomalous dimensions.

Topological defects appear very often in spontaneously broken field theories as classical solutions, which can be created dynamically during phase transitions. They may have an important role in the evolution of the early universe, because a large number of cosmic string-type defect solutions have been found in semi-local theories, where stability does not arise „automatically" from the topology of the defects. RMKI researchers investigated the stability of recently discovered twisted string-type defect solutions in Abelian Higgs models with global SU(2) symmetries. It was proved that these defects obey instable modes that can be characterized by wave numbers along the strings. The nature of these instabilities has been clarified successfully by a semianalitic description of the instabil modes at the twist parameter range close to the bifurcation values.

Recent theoretical investigations led to a surprising result: gravitation can be connected to the collapse of the quantum mechanical wave function. Thus the quantum mechanical localization of macroscopic bodies and the existence of gravity assume each other. A mathematical model of this connection has been elaborated. It was shown that the well known quantum Boltzmann equation is not capable to handle the decoherence of momenta during quantum Brown motion. Consequently, a new equation was introduced, which describes this decoherence correctly.

A new numerical method has been developed to describe the gravitational collapse of stars and the formation gravitational waves. Recent developments in the field of numerical relativity offer precise information on gravitational wave forms, which can be used to great advantage in gravitational wave experiments. These new results have been already taken into consideration in the VIRGO gravitational wave detection collaboration, in which RMKI researchers participate actively.

The theoretical and phenomenological studies have revealed common features of black holes and the central limit theorem of probablility theory concerning their entropy. This connection is validated for the „no hair" theorem of black holes, for the entropy maximalization, for the Susskind-process leading to the holographic entropy limit, and for the quantization of black hole entropy. This result has been awarded by laudation on the essay competition of the Gravity Research Foundation in 2009.

Stability and causality are requested from the basic equations of relativistic hidrodynamics, conditions which are hard to satisfy in every cases. A new solution has been found in the relativistic extension of the dissipative Fourier-Navier-Stokes equations, which will become stable by fulfilling simple conditions. This was ensured by a particular relativistic generalization of inner energy, mechanical work, and entropy.

Experimental results of antikaon-nucleon scattering can be reproduced by theoretical calculations using either weakly or strongly bound two-body systems. It was suggested that

this discrepancy can be solved by investigation of special three-body systems, as antikaon-proton-proton and antikaon-deuterium. The detailed analysis of three-body interactions can decide between the weakly and strongly bound scenarios.

Plasmaphysics and the physics of cooled atoms

In the field of fusion physics research for several European fusion experiments further technical developments were carried out. The construction of the two-dimensional Beam Emission Spectroscopy system for the MAST tokamak has been completed in collaboration with two spin-off companies of RMKI. This device will be unique in Europe and aims at measuring plasma turbulence (both in the core and at the edge of the tokamak plasma) and plasma flows via detecting fluctuations in the light emission of a deuterium heating beam. In the edge plasma of the TEXTOR tokamak the Lithium beam Emission Spectroscopy system detected so-called Geodesic Acoustic Modes (GAMs). These flow modulations are believed to play a crucial role in the self-regulation of plasma turbulence. The measurements have also demonstrated that the same Li-beam diagnostic is capable of measuring plasma density changes on the 10 microsecond timescale.

The COMPASS tokamak is being restarted in Prague and RMKI researchers are building there new lithium-beam diagnostics similar to that of the TEXTOR machine. A novel feature of the diagnostics is the detection of ions stemming from the atomic beam. From the ion beam movement the edge plasma current density can be calculated which is extremely important for the verification of theories of the ELM instability. The major components of the diagnostics system became ready in 2009; the system will be installed in the first half of 2010.

The threat of plasma disruption in tokamak devices is well known. Just as with ITER the effects might be extremely dangerous, so that their mitigation is of upmost importance. One of the possible disruption mitigation techniques is the fast injection of a large amount of neutral gas. For studying this disruption mitigation scheme researchers of RMKI have designed, built and installed a supersonic gas injector for the TCV tokamak. This device is capable of injecting in one millisecond more gas atoms than the number of ions in the plasma.

In order to better understand the pellet ELM triggering processes the pellet-driven magnetic perturbation was studied for three different plasma scenarios in the ASDEX Upgrade tokamak. According to the observations the pellet ablating in the plasma launches broadband Alfvén waves and reduces the frequency of the toroidal Alfvén eigenmodes - naturally present in ohmic plasmas - by fuelling. From the results of these investigations it was concluded that the ELMs triggered by the pellet injection are probably not generated by the pellet-caused magnetic perturbations but by the pellet-caused plasma edge pressure perturbation. By means of the newly developed fast framing CMOS camera system in the JET tokamak it was observed, that the perturbation evolving into an ELM instability is directly growing out of the cloud of the ablating pellet.

The 10 channel video diagnostics system designed by RMKI scientists for the Wendelstein-7X stellarator is under construction in Greifswald, Germany. For this diagnostics a fast (up to 100 kHz frame rate) and intelligent CMOS camera is under development. In 2009 the final version of the camera hardware was manufactured including the 10 Gbit communication link connecting the camera head with the image processing and control unit.

RMKI engineers play a substantial role in developing diagnostic systems and designing the test tritium breeder (TBM) cassettes for the ITER device. In the diagnostic field the numerical

simulation of the bolometer diagnostic cameras has been completed. As a result an ANSYS code is available now, which can be used in the future to predict how different detector constructions behave under various heat loads from the plasma. For the TBM system the 60 metric ton heavy frame and the internal arrangement of modules have been designed, taking into account the requirements for manufacturing, assembling and maintenance.

In the field of laser-plasma interactions researchers of the RMKI in collaboration with the University of Szeged team showed that the reflectivity of the high-power KrF laser beam focussed onto solid targets increases logarithmically above the plasma threshold. Above the intensity of 10^{14}W/cm^2 the plasma is becoming fully ionized and the reflectivity saturates. More than 40% reflectivity was obtained, which shows the direct applicability of plasma mirror for the "cleaning" of ultrashort KrF laser pulses. The applicability of the plasma mirror before the last amplifier seems to be even more feasible for our experimental conditions. These novel schemes will be applicable not only for KrF laser systems but for longer wavelength solid state systems like the future ELI and HiPER as well. These results have importance not only for basic research but may gain further significance in the realization of laser-driven inertial fusion, too.

A successful application within the frames of LASERLAB Europe allowed the RMKI researchers to participate in an experiment in the Max-Planck-Institut für Quantenoptik (MPQ) at Garching. The dependence of high-harmonics generation from the polarization (and ellipticity) of the 3-cycle (8fs) laser beam was studied. The polarization of the generated harmonics was investigated as well, with a home-made polarization analyzer. It was shown that in the polarization of the harmonics generated by a 3-cycle laser the p-component, i.e., the electric field component in the plane of incidence, dominates.

In the field of the cold plasma and laser manipulation of the atoms, two novel methods of creation of "on demand" coherent superposition states have been developed using frequency chirped laser pulses in the atoms with Λ-structure of the working levels. The suppression of excitation allows one to avoid decoherence processes due to spontaneous decay of the excited state. The first method is using two laser pulses with carrier frequencies far off-resonance with allowed transitions in the atom. The second method is based on the interaction of the atom with two laser pulses having large Raman detuning with frequencies chirped through the single photon resonances in the Λ-atom.

A novel scheme of writing and long-time storage of phase and amplitude information (transverse images) has been developed, also applicable in case of solids. The information is stored in long-living metastable states of multilevel atoms. The transversal picture is read out by a further laser pulse. Broad inhomogeneous transition lines characteristic for solid-state systems were assumed in the numerical simulations. The proposed scheme has been demonstrated on the model of an atom with tripod-structure of the working levels. Their methods could be used in quantum-informatics applications and in amplification of resonant nonlinear optical effects in solid and gaseous substances.

In the frame of an international OTKA grant, in the cloud of Rb atoms cooled and trapped in the magneto-optical trap (MOT) the process of electromagnetically induced transparency (EIT) has been investigated. As the theoretical analysis has shown, the use of the frequency chirped laser pulses may substantially widen the transparency window in the EIT process as compared with the schemes utilizing constant carrier frequencies. As a result, much shorter laser pulses may be slowed down or stopped in the medium.

Space physics and space technology

The scientists of the institute conducted experimental and theoretical research in space physics and in space technology but they also carried on methodical and instrumental development activities, too. The Rosetta-Philae space probe pair of the European Space Agency was launched to comet Churyumov-Gerasimenko in 2004; Philae is scheduled to land on the surface of the cometary nucleus in 2014. The in-flight corrections of the parameters of the instruments and of the comet require continuous fine-tuning of the software. Our scientists, as software developers of the central computer of Philae, are actively participating in this procedure. An updated software version to be uploaded to the lander computer before hibernation has been completed.

The data acquisition software of the 3-unit computer system of the Plasma Wave Complex to be flown aboard the International Space Station was also finalized by the RMKI staff. The flight model was delivered to Russia in February 2009. The tests were succesfully completed in Moscow, the manufacturing of the reserve model is in progress.

Scientists of RMKI participating in the Cassini mission to explore planet Saturn and its environment enriched our understanding about moon Titan with new elements. They pointed out that many features of the T9 Titan flyby were presumably caused by the fact that Cassini entered the magnetodisk of Saturn before the encounter, a region dominated by protons where the direction of the beam reaching Titan has changed. The nighttime ionosphere of Titan is exclusively due to magnetospheric electrons. The density, temperature, and velocity momentum calculated from the primary mission helped to begin the comprehensive study of the magnetodisk, which forms a kind of trap for magnetospheric ions, heavier (water group) ions are concentrated within a very narrow region whereas protons are found in a larger volume. The quantitative analysis of the relationship between the magnetodisk and magnetospheric ions supported the models depicting the magnetodisk as an asymmetric rotating object. The probe approaches Titan under essentially different conditions in the course of subsequent flybys which were classified according to the ion data. It has turned out that one of the most important factors affecting the flyby circumstances is the position of the spacecraft relative to the magnetodisk.

The Ulysses spacecraft performed measurements in the heliosphere in a polar orbit around the Sun between 1992 and 2009. During the first period in 1995 when it was close to the Sun, in the energetic particle fluxes a North-South asymmetry was revealed, that was explained by a 10° southward shift of the current sheet dividing the opposite magnetic polarity regions of the heliosphere. By analyzing the locations of the sector crossings observed by Ulysses, scientists of the institute determined the average shift of the current sheet during the first and third orbit sections near the Sun in 1995 and in 2007, respectively. They pointed out that the small extent of the shift is incompatible with the 10° value needed to explain the particle fluxes. The slight southward shift observed in both solar cycles confirms the earlier results obtained from observations performed at the Earth orbit.

The RMKI project proposal entitled SOlar-TERrestrial Investigations and Archives (SOTERIA) submitted together with 15 European collaborating institutes acquired support from the Seventh Framework Programme of the EC (FP7-SPACE-2007-001, project number 218816). The project realized a widespread collaboration in the field of solar physics, space physics, and geophysics by simultaneous observations with ground-based and space

instrumentation through the analysis of a large number of solar originated geoeffective space weather events. Our scientists take part by modelling the space weather and the outer boundaries of the terrestrial magnetosphere. Based on the temporal evolution of the fluxes of a particle event, they found that for the arrival time to the Earth the velocity of the shock wave obtained near the Sun from optical observations yields inaccurate values, which were necessary for predicting space weather events.

RMKI reserachers have completed the laboratory model of the power supply unit for the Plasma Ion Camera of ESA's BepiColombo mission starting to Mercury in 2014.

The RMKI engineers have performed the software and hardware modifications on the calibration system at Kiruna necessary for the post-calibration of the ASPERA particle detector of the Venus Express space probe.

Biophysics

Recent simulations related to their ICEA project demonstrated that parametric changes in entorhinal and hippocampal spatial representations following morphing of the environment are the result of a reciprocal interaction between the two areas. Their model describing the process of self-localization within the rodent hippocampus is used to develop robotic navigational algorithms by their European partners. It was shown by analytical calculations that the receptive field of neurons in the medial entorhinal cortex that form a regular triangular grid-like pattern (hence their name "grid cells") is an optimal representation of the metric space. Moreover, spatial activity pattern is also optimal in the sense that it requires the minimal number of spikes within the neural population to represent a given area with a fixed precision.

Investigating the neural basis of the large amplitude and low-frequency oscillatory rhythms appearing in evolving networks they demonstrated that GABA-A currents have a permissive role in the formation of the giant depolarizing potentials (GDPs), however, these currents do not have an initiative effect.

In an international collaboration, interaction of low-level and high-level cues in a visual stimulus was investigated while human subjects were engaged in a visual learning task. Two experiments were designed and performed in which these two factors were selectively controlled and human performance was compared with the predictions of an ideal learner. It has been shown that independently of the length of the training, low-level cues provide a strong prior information for humans in visual scene segmentation, which results in sub-optimal performance in learning. Using a control experiment it has also been shown that the elimination of low-level cues rectifies optimal performance in the visual learning task.

The integration of auditory and visual stimuli during speech perception in an EEG experiment was investigated, the limitations of classical analyses were pointed out and a new methodology was proposed to overcome it. It was found that components corresponding to both auditory N1 and P2 waves, that appear 100 and 200 ms after the stimulus, respectively, were suppressed in case of multimodal integration, and the two components showed different degree of hemispheric dominance.

A model-based method applicable in the medical praxis, suitable for the choice of optimal, personalized treatment of AIDS-affected patients was also developed. The condition of the patients and the state of the viruses comprised the undersampled input data of the model, while from methodological point of view, the outcome of the treatment was the output value.

Using statistical and data-mining techniques a relation between input and output was established identified.

In an international collaboration, a family of models was introduced to explain the public budgeting process as a multi-stage institutional decision making procedure. A set of threshold models, reflecting error-accumulation and friction at different stages, describe appropriately the basic statistical features of the data.

Informatics and e-science

The operation and development of the CERN LHC GRID was a continuous task, well mastered with the cooperation of the other Departments of RMKi involved in this project. This professionality resulted in the high operational safety of the BUDAPEST GRID system.

Within the framework of the Mobile Assistant project (GVOP - 2004 – 3.1.1), employing the Nav-N-Go Ltd. navigations engine, a GPS navigation system has been developed for blind users and was handed out to 20 persons for test. The implantation and training of the Mobile Assistant system has been continued with 23 new participants. Consultation with and support of the previous users (100 blind persons) have also been continued.

A Talkpad touch-pad software has been designed for facilitating the communication of autists persons, this program is now in the test phase. The coworkers of the Department gave support also to three M.Sc. theses completed at the Pannon University. The researchers of the Rehabilitation Technology Department gave six presentations at the Blind People's Organization on the MOST project, and one lecture was given at the Commerce Angel Club, too. Two reports featured their achievements in the Duna TV Heureka magazine, and one report was shown on MTV1.

Other results and special events

Five researchers of KFKI RMKI were included in the NASA „Award of excellence", given to the Plasma Spectrometer Group in the Cassini Mission for outstanding contribution to the scientific success of the project.

The leading scientists of RMKI have played a dominating role in the media and web presentations of news connected with the restart of the LHC accelerator at CERN. These undertakings contributed to science popularization, to a better public understanding and acceptance of the connected scientific goals and have increased the visibility and recognition of the Institute.

The „Zimányi Winter School on Heavy Ion Physics" has been organized the 9th times by now, and with over 50 regular participants and cca.40 lectures it became an acknowledged and important event in this field of research.

The „Particle Physics" interactive one-day video-workshop for high-school students has been organized the 6th times, in cooperation with cca. 70 research institutions and universities from 30 countries from Europe and overseas. Regularly, at KFKI RMKI two dozens of students participate from 10-10 high schools.

It is was the 5th times in 2009, that the Simonyi Day was organized both for the coworkers of the institute and for the public at large: the lectures given on outstanding achievements of the researchers of the insitute were received with great attention and interest.

III. Presentation of national and international relations

The relationship between RMKI and other research institutions of the Hungarian Academy of Sciences is traditionally very fruitful, especially with those residing in the KFKI Campus as well as with the Institute of Nuclear Research (ATOMKI) in Debrecen, Hungary. The close collaboration with the institutions on the KFKI Campus is best illustrated by the fact that RMKI is a member of the KFKI Condensed Matter Research Center (CMRC) -together with the Research Institute for Solid State Physics and Optics (SZFKI), the Atomic Energy Research Institute (AEKI) and the Research Institute for Technical Physics and Materials Science (MFA)-, as well as that of the Budapest Neutron Center (BNC). The traditionally strong ties with ATOMKI are demonstrated by the joint projects in the field of high energy physics, the collaboration in the research and development in the framework of the Hungarian Ion-beam Physics Platform, (HIPP, http://hipp.atomki.hu/) and the participation in the activity of the European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT, Trento, Italy) organized by the ECT Hungary Consortium. There also exist active working relations with the researchers of the Chemical Research Center (KKKI), the Computer and Automation Research Centre (SZTAKI), the Konkoly Observatory and the Biologocal Research Center (SZBK) of the Hungarian Academy of Sciences. The Computing Center of RMKI is the regional center of the NIIF program, with two of our scientists sitting in committees of NIIF. RMKI is also member of the Hungarian Grid Competency Center.

RMKI researchers act as chairpersons in the Syncrotron Committee, the Dubna Committee as well as in the International Theoretical Workshop (NEFIM) Board: in these, for the whole Hungarian scientific society important bodies the administrative as well as financial service is provided by the RMKI staff.

The RMKI attributes high priority to the close ties with universities and regards teaching as an important part of the basic duties of research. In the year 2009, forty RMKI scientists have been lecturing at various departments of the Eötvös University, the Budapest Technical University, the University of Szeged, the University of Pécs, the Szent István University, the Central European University and the Budapest School of Cognitive Sciences. In addition, with all those institutions they established working collaboration in various research topics. Our scientists have given lectures at a number of foreign univeristies in the field of nuclear physics, particle physics, gravitation heory, field theory and quantum mechanics. The lecture series on „Nuclear Solid State Physics" at the Faculty of Science of Eötvös University was traditionally part of the curriculum and our researchers took part in the organization of the ERASMUS School (May 2009, Bonn-Bad Honnef, Germany) on *„Engineering and characterisation of nanostructures by photon, ion beam, and nuclear methods",* accredited also to the ELTE Physcis PhD School. At the Budapest Technical Univerity a special series of lectures was held on *„Investigation Methods in Materials Science"* dealing with methods of nuclear analytics as well as Mössbauer spectroscopy. At the Faculty of Science of Eötvös University a course on „Computer modelling of the nervous system", at the Budapest School of Cognitive Sciences a course on computational neuroscience was held. At the Szabadka Technical High School a course on physics, while at the Szent István University the course on biophysics were regularly held both in Hungarian and in English. As a result of the intensive collaboraton a large number of master's (17) and PhD (23) theses have been prepared in RMKI. Upon the signed agreements with the ELTE, BME and the Szeged University, the RMKI researchers also act as grounding members of the PhD Schools of the respective

universities and they actively influence and shape the thematic spectrum of the courses where they also lecture.

In the RMKI almost all research is conducted in international collaboration. The most important partners are the CERN, ESA and EURATOM. In addition, RMKI is the coordinator of the PHENIX-HUNGARY experiment at the RHIC accelerator of the Brookhaven National Laboratory with the participation of Eötvös University and Debrecen University. With the active participation of our researchers important results are expected in the coming years in the PHENIX (RHIC, USA) experiment to generate quark-gluon plasma as well as at the ALICE, TOTEM high energy nuclear physics experiments at the LHC in Switzerland. It is important to note that for the next two years an RMKI scientist was elected to serve as associate coordinator of the QCD experimental team. Our researchers have played an influential role in the KATRIN particle physics experiment (Germany) to measure the neutrino mass. Attempts for joining the GSI/FAIR medium energy nuclear physics experiment have been strengthtened. RMKI researchers have also taken an active part in the VIRGO (Italy) experiment to detect gravitational waves which they joined in 2009. The research conducted at foreign, primarily European large devices (syncrotrons, ion accelerators, neutron sources, tokamaks and stellarators) or aimed at their development (eg. ITER, ELI) is ever increasing in importance. Also essential are the bilateral and multilateral collaborations with numerous other research institutions. In the field of nuclear solid state physics and space hysics there is ongoing collaboration with 35, in particle physics with more than a hundred institutes including even the most prestigious ones. In the results achieved an important contribution can be attributed to the bilateral agreements of the HAS as well as the HAS-JINR (Dubna) joint projects, too. The Hungarian Fusion Program is coordinated by RMKI as the leader of the Euratom Fusion Association with the partcipation of other Hungarian institutions (KFKI AEKI, Széchenyi University, ATOMKI, Budapest Technical University, College of Dunaujváros). RMKI researchers are working in a number of the resepctive international committees and even in the presert phase have joined the design works of ITER, the world's first fusion reactor. The sign of the international recognition of our contributions in this field is the fact that Hungary was chosen to host the 31st ECLIM Conference with an RMKI researcher as its chairman.

The Cluster Hungarian Data Center, operated by RMKI provides trajectory as well as other supplementary data to the four Cluster stallites of the European Space Agency (ESA).

In the field of biophysics (computational neuroscience) active collaboration supported by a number of international scholarships is going on with Kalamazoo College (Michigan University, USA) just as well as with the Brandeis Univerity (Waltham, USA) and the University of Cambridge, UK. A research contract has been signed with the Pfizer Pharmaceutical Company, in frame of which the scientific analyzis of electrophysiological data is carried out by the RMKI group.

The researchers of RMKI are serving in a large number of national committees, e.g., the Eötvös Physical Society, Bolyai Curatorium, Hungarian Space Research Council, etc. They also play an active role in the international scientific community. The most important foreign scientific institutions where RMKI is represented are: the CERN Council and its Committees, the EURATOM Scientific and Technical Committee, EFDA Science and Technology Advisory Committee (vice-chair), Expert Committees of the IAEA, Joint Undertaking for ITER Governing Board, EFDA Steering Committee, the European Physical Society (EPS), International Astronautical Academy (Board of Trustees, International Space Science

Committee), COSPAR, European Science Forum on Research Infrastructures, FP7 Research Infrastructures Program Committee with the European Committee, the IUPAP, COST DC MPNS (Domain Committee for Materials, Physcial and Nanosciences), COST TDP SAB (Trans-Domain Proposals Standing Assesment Body), ESF Standing Committee for Physics and Engineering (PESC) and NUPECC, ESF Member Forum on Science Careers, European Neural Network Society Executive Committee, the EuGridPMA (European Policy Management Authority for Grid Authentication), an international working group to develop Linux kernel netfilter/iptables components, etc.

According to the decision made in 2009 by the European Union, Hungary will host the future Extreme Laser Infrastructure (ELI) and Research Center. In the Hungarian Consortium the researchers of RMKI are present and are preparing the various applications.

A number of RMKI researchers are members of various scientific committees of their respective research fields as well as of editorial boards of a number of international journals. In addition to numerous invitations to give lectures at conferences they are repeateadly invited to serve on high ranking scientific panels (eg. ERC Advanced Grant Evaluational Panel, ERC Starting Grant remote evaluation, COST Proposal Evaluational Board, CNRS etc.), too.

IV. Brief evaluation of successful national and international grants

In addition to the budget provided by the Hungarian Academy of Science the expenses of the research conducted by RMKI are funded by succesful applications to EU FP6-FP7, OTKA, NKTH, HAS-National Science Foundation (USA), HAS-JINR (Dubna) as well as by NKTH TÉT bilateral collaboration schemes. One of the major projects started in 2009 was the NAP-VENEUS-08 (NKTH) project which supported the construction of the polarized neutron refractometer as well as its test runs at the Budapest Research Reactor.

The device constructed in the frame of the FP7 access program is unique in our region. The technological results of the NAP-VENEUS-08 project (super mirrors and the recycling of the isotope enriched test gas of gas detectors) have been obtained primarily by the Mirrotron Kft. With the financial support of the project, a multiuse unique software was also developed to simultaneously analyze and fit the measured data. The project in 2009 funded two manyears employment.

The research conducted at CERN has obtained a sizeabla support from successful NKTH-OTKA Mobility Grant aplications. Equally important are the successful applications for beam time at the large European facilities (syncrotron, neutron source, etc.).

The focal points of plasma physics research are the EURATOM collaborations and the participation in the development of ITER. The successful applications obtauined so far guarantee a long term continuation of the research.

In the field of space physics and space technology support has been obtained from OTKA, the Hungarian Space Office as well as from five different ESA PECS (Program for European Cooperating States) contracts, the last ones connected with the Rosetta, Cluster, Venus Express and Bepi Colombo space programs. Since Hungary is not a member state of the European Space Agency, the participation in ESA projects is supported in the frame of the Program for European Cooperating States (PECS).
RMKI researchers also continued their work in the frame of the Integrating Cognition Emotion and Autonomy (IST-4-027819-IP) EU grant and their yearly report has been valued

high. In this field, one of the young reserachers won an Eötvös Scholarship of the Hungarian State for a three months stay at the University of Cambridge in order to study the motion of the human eye.

V. The most important publications and patents in 2009

1.Abbiendi G, Ainsley C, Akesson PF, Alexander G, Anagnostou G, Anderson KJ, et al., (210 authors included: Csilling Á, Hajdú C, Horváth D)
Sigma(-)-antihyperon correlations in Z(0) decay and investigation of the baryon production mechanism
EUR PHYS J C **64**: (4)*609-625* (2009)

2.Afanasiev S, Aidala C, Ajitanand NN, Akiba Y, Alexander J, Al-Jamel A, et al., (345 authors included: Csörgő T, Ster A, Sziklai J, Zimányi J)
Charged Kaon Interferometric Probes of Space-Time Evolution in Au plus Au Collisions at s(NN)=200 GeV
PHYS REV LETT **103**: (14) (2009)

3.Anticic T, Baatar B, Barna D, Bartke J, Betev L, Bialkowska H, et al., (93 authors included: Csató P, Fodor Z, Hegyi S, László A, Lévai P, Molnár J, Palla G, Siklér F, Szentpétery I, Sziklai J, Varga D, Veres GI, Vesztergombi G,)
Energy dependence of transverse momentum fluctuations in Pb plus Pb collisions at the CERN Super Proton Synchrotron (SPS) at 20A to 158A GeV
PHYS REV C **79**: (4) (2009)

4.Balog J, Niedermayer F, Weisz P
Logarithmic corrections to O(a(2)) lattice artifacts
PHYS LETT B **676**: (4-5)*188-192* (2009)

5.Bíró TS, Ürmössy K
Transverse hadron spectra from a stringy quark matter
J PHYS G NUCL PARTIC **36**: (6)*064044* (2009)

6.de Groot F, Vankó G, Glatzel P
The 1s x-ray absorption pre-edge structures in transition metal oxides
J PHYS CONDENS MAT **21**: (10)*104207* (2009)

7.Diósi L
Quantum linear Boltzmann equation with finite intercollision time
PHYS REV A **80**: (6)*064104* (2009)

8.Djotyan GP, Sándor N, Bakos JS, Sörlei Z
Optical phase information writing and storage in populations of metastable quantum states
J OPT SOC AM B **26**: (10)*1959-1966* (2009)

9.Facskó G, Németh Z, Erdős G, Kis A, Dandouras I
A global study of hot flow anomalies using Cluster multi-spacecraft measurements
ANN GEOPHYS-GERMANY **27**: (5)*2057-2076* (2009)

10.Fodor Gy, Forgács P, Horváth Z, Mezei M
Oscillons in dilaton-scalar theories
J HIGH ENERGY PHYS : (8) (2009)

11.Forgács P, Lukács Á
Instabilities of twisted strings
J HIGH ENERGY PHYS : (12)*064* (2009)

12.Hegyi S
SIMPLE OBSERVATIONS CONCERNING BLACK HOLES AND PROBABILITY
INT J MOD PHYS D **18**: (14)*2269-2273* (2009)

13.Huhn Z, Somogyvári Z, Kiss T, Érdi P
Distance coding strategies based on the entorhinal grid cell system
NEURAL NETWORKS **22**: (5-6)*536-543* (2009)

14.Lévai P, Skokov VV
Strange and charm quark-pair production in strong non-Abelian field
J PHYS G NUCL PARTIC **36**: (6) (2009)

15.Majár J
Spin-spin interaction in the spin-precession equations
PHYS REV D PART FIELDS GRAV COSM **80**: (10) (2009)

16.Saad A, Fedotova J, Nechaj J, Szilágyi E, Marszalek M
Tuning of magnetic properties and structure of granular FeCoZr-Al2O3 nanocomposites by oxygen incorporation
J ALLOY COMPD **471**: (1-2)*357-363* (2009)

17.Smith HM, Fehér T, Fülöp T, Gál K, Verwichte E
Runaway electron generation in tokamak disruptions
PLASMA PHYS CONTR F **51**: (12) (2009)

18.Szabados LB
Towards the quasi-localization of canonical general relativity
CLASSICAL QUANT GRAV **26**: (12)*125013* (2009)

19.Szegő K, Bebesi Z, Dobe Z, Franz M, Fedorov A, Barabash S, et al. (8 authors)
O+ ion flow below the magnetic barrier at Venus post terminator
J GEOPHYS RES **114**: (2009)

20.Szepesi T, Kálvin S, Kocsis G, Lackner K, Lang PT, Maraschek M, et al. (8 authors)
Investigation of pellet-driven magnetic perturbations in different tokamak scenarios
PLASMA PHYS CONTR F **51**: (12) (2009)

21.Szőkefalvi-Nagy Z, Kocsonya A, Kovács I, Hopff D, Lüthje S, Niecke M
High resolution imaging and elemental analysis of PAGE electrophoretograms by scanning proton microprobe
NUCL INSTRUM METH B **267**: (12-13)*2163-2166* (2009)

22.Ujfalussy B, Kiss T, Érdi P
Parallel Computational Subunits in Dentate Granule Cells Generate Multiple Place Fields
PLOS COMPUT BIOL **5**: (9)*e1000500* (2009)

23.Ván P
Generic stability of dissipative non-relativistic and relativistic fluids
J STAT MECH-THEOR E : (2009)

24. Vértesi R, Csörgő T, Sziklai J
Significant in-medium eta ' mass reduction in root s(NN)=200 GeV Au+Au collisions
NUCL PHYS A **830**: (1-4)*631C-632C* (2009)