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The 2002 awardee: Ákos Horváth

Curriculum Vitae of Ákos Horváth, the 2002 awardee

I'm Ákos Horváth, the 2002 awardee. I graduated at Eötvös Loránd University Faculty of Sciences (ELTE) as master in engineering-physics in 1995. During the years at the university I followed engineering courses at Miskolc University, Faculty of Materials Science. I also spent 6 months as a scholarship holder at the St. Jérôme Faculty of Sciences, Marseille, France.

After the University I went to the Atomic Energy Research Institute as a PhD student. I have chosen corrosion related problems as the subject of my thesis. Finally I defended my PhD in electrochemistry in 2003. Besides the corrosion experiments I have given lectures on informatics at ELTE and corrosion laboratory practice at the Budapest University of Technology and Economics.

I spent a few years with validating two subsystems of the Temelin Nuclear Power Plant. In this work I learnt much about industrial software, nuclear safety and reliability. The work was supervised by the former Westinghouse Company.

I had the opportunity to work for one year at the IFE Halden Reactor Project in Norway. Being a secondee, my primary task was following some corrosion and stress corrosion cracking experiments, and evaluating the data. This experience at the Halden Project has given a good overview of the materials degradation issues of nuclear reactors. It was also a great opportunity to make contacts with people from the nuclear community.

In my free time I like to travel. I prefer the sightseeing of old cities, but I was overawed by the fjords of Norway as well. I am married and we have two little daughters.

Local corrosion and the effect of deformation of corrosion resistant metals by electrochemical methods

ÁKOS HORVÁTH
HUNGARIAN ACADEMY OF SCIENCES KFKI ATOMIC ENERGY RESEARCH INSTITUTE

Introduction

My tasks were partly based on the basic research and were partly of technological nature, all being in connection with the corrosion processes in nuclear power plants. The structural materials of the primary circuit of the reactors are resistant to general corrosion. However they are subject to deformation, mechanical stress of thermical origin and to erosion. Moreover one has to take into consideration also processes of local corrosion. Some of these aspects of the above mentioned phenomena are the subject of the thesis.

It is a well-known problem that the corrosion processes, which take place in electrolyte solutions, have a considerable influence on the dynamic mechanical properties of the structural materials. For example there is a decrease in the fatigue limit, tensile strength, the critical stress needed for crack propagation. Stress corrosion cracking experiments were carried out under various environmental conditions and with a number of structural materials. There are some empirical models for the estimation of technical parameters however, fundamental aspects of the subject, for example the effect of deformation of the bulk metal on the potential of the metal/electrolyte interface is poorly known. The choice of the subject was motivated by the connection between the mechanical properties of the metals and the electrochemical science, which is both interesting and practically important. For the metallurgist and the metal physicist the solid metal is primarily an extensive bulk phenomenon while the electrochemist is "interested" in the surface. In studies of the solid-liquid interface we most often believe that the bulk characteristics of the solid phase are constant. This view is reflected by the general discussions of electrochemistry.

Aiming at extending our knowledge in the stress corrosion cracking problem, I have studied the effect of mechanical stress on the electrode potential in a series of laboratory experiment. We concluded in a model describing the connection between elastic mechanical stress and electrode potential.

Noise spectra and kinetics of any physical process are known to be closely correlated; the measurement and analysis of noise spectra render methods of rate determination that do not perturb the equilibrium or steady state of the system under study. In this vein the random fluctuations of electrode potential or current, usually called electrochemical noise, give insight into the dynamics of electric processes which take place at the solid/liquid interface. The corrosion potential noise analysis is a simple and promising method for corrosion monitoring in nuclear plants or spent fuel storage systems. Rescaled range analysis (*R*/*S* or Hurst method) is a fast and reliable technique for noise analysis particularly if mechanistic information is needed. The robustness and reliability of this method was demonstrated by the quantitative characterisation of local corrosion of freely corroding metals.

As a practical application of the Hurst analysis, a kinetic model was developed in view of which the formation of the corrosion products in a VVER type nuclear power plant was evaluated. The Hurst method was used to characterise the random or deterministic nature of corrosion processes.

Results

1. The effect of the bulk mechanical stress on the electrode potential of the electrode was studied. It was shown that the mechanical pre-treatments, i.e. the mechanical properties of the metal electrode, are key parameters as far as the reproducibility of the measurements is concerned. The results were interpreted in terms of the electrostatics of the double layer enabling one to evaluate the stress dependence of the potential of zero charge. The experimental value was supported by a theoretical estimation.
2. It was shown with the analysis of the corrosion potential noise that the Hurst analysis is a reliable method for the monitoring of general and local corrosion phenomena. The advantages of the method were demonstrated through numerical simulations and a properly chosen model electrode. By the analysis of pitting corrosion I have found differences between the extent of correlation in the range of short and long time, which leads to the mechanism of corrosion.
3. In the critical analysis of the primary circuit chemistry data of Paks Nuclear Power Plant a kinetic model was given for the formation of corrosion products, whereas the Hurst method was used to characterise the random or deterministic nature of chemical processes. It was found that the primary circuit operational conditions are within the designed limits from the

point of view of corrosion. According to statistical treatment of the data it was shown that random events play little if any role and the processes in the coolant are under control. The result of the Hurst analysis is $H\cong 1$ in most of the cases. This lead to the conclusion that the physical and chemical processes are strictly persistent i.e. deterministic.

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The 2003 awardee: Anikó Kerkápoly

Curriculum Vitae of Anikó Kerkápoly, the 2003 awardee

I am Anikó Kerkápoly, native in Budapest – it's the town where I was born, where I studied, lived, and work. I graduated as major in Engineering-Physics at the Budapest University of Technology and Economics (BME) in 2001. In my youth I always wanted to be an archaeologist, astronomer, physician, and biologist – preferably all at once – but finally I ended up as a physicist (and teacher, but more on that a bit later).

In high school I studied biology on an advanced course (I wanted to be a physician/biologist, remember?), but while preparing for a competition in the second class, I fell in love with the radiation. As a consequence, I decided to go to the BME.

At the university, many people are pondering a lot over which faculty to choose. I haven't had such problems; mine was a straight course to the Institute of Nuclear Techniques. After all, that was why I came to this university in the first place.

While I was studying at BME, I have also completed a physics-teacher course, so I could teach in high schools as well. It's so much fun to teach in a high school and so different from the university...

I wrote my diploma thesis and my paper for the National Scientific Student's Conference about the examination of environmental samples contaminated because of the nuclear accident at Chernobyl. Since this required a lot of radiochemical work, I had to get into chemistry as well. I didn't mind it at all; I really enjoy working in a chemical laboratory.

After graduation, I devoted myself to my two hobbies: I started to work on my PhD with the topic of hot particle examinations, and I also teach part-time physics in a high school. Currently I work as a researcher at BME and teach obsessively.

Oh, yeah, a good CV should describe what you do in your free time. Well, my hobbies are (among others): travelling (I just love it), reading, playing basketball (I was a member of the high school team!) and teaching. The latter is neither too profitable, nor relaxing, but really exciting. I also got married and live happily with my husband.

Examinations of hot particles originating from the primary coolant of a nuclear reactor and from several other sources

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INSTITUTE OF NUCLEAR TECHNIQUES

Introduction

The increase of the activities of fission and transmutation products in the primary coolant is the consequence of fuel failures. One part of the contamination of the primary circuit is in soluble fraction, but the other part of the activity is bound to particles. From failed fuels with macro leaks fuel fragments can escape into the coolant. By the identification, micro- and radioanalytical examinations of these hot particles more information about the fuel failures can be obtained than by measuring only the activity concentration of the primary coolant or bulk samples. In connection with my PhD education micro- and radioanalytical methods were developed and adopted for the complex examination of individual fuel particles originating from the primary water of Nuclear Power Plant Paks. With the characterization of individual fuel fragments information can be obtained about the fuel failures at NPP Paks.

Fuel fragments can be released not only during normal operation conditions. In April 2003 a serious incident (according to the INES scale) happened at NPP Paks. During a chemical cleaning process of burnt fuel elements 30 assemblies were damaged because of insufficient cooling. From the damaged fuel elements volatile and non-volatile radionuclides were released into the coolant. A part of the activity was in soluble form, but another part of the released activity was in form of particles.

The developed particle examination techniques (used for analyses of the particles taken from the primary coolant) were adopted for the analysis of the hot particles originating from the incidentally contaminated water at NPP Paks. With the examination of the fuel fragments originating from the damaged fuels, information about the dissolution process of the fuel debris can be obtained.

Examination methods and results of the examinations of hot particles connecting to NPP Paks

Samples

Particles collected from the coolant during transient operational conditions (reactor-shutdown)

Usually one litre of primary water was filtered through Millipore membrane-filter of 0.1 and 0.4μm pore size. Samples were taken at Unit 2 and 3 in 2003.

Particles collected from the coolant contaminated by the fuel debris due to the incident

In case of the particles originating from the damaged fuels, usually some millilitres of water were filtered through Millipore membranes of 0.1μm pore size.

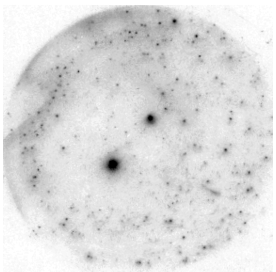

Figure 1. Autoradiogram of a Millipore filter with hot particles (1ml water was filtered trough the membrane, exposure time was 1420 minutes, the water was collected from the incidentally contaminated storage pool of NPP Paks on February 02, 2004)

Autoradiography

Identification of the hot particles on the Millipore membranes was carried out by film autoradiography using a Hungarian black and white film (Fortepan 100) that was sensitive mainly to alpha-radiation. The examined hot particles contain alpha, beta- and gamma-emitters. Owing to the high activity range of the samples (in case of the hot particles taken from the primary coolant during reactor-shutdown or from the incidentally contaminated water) the exposure time ranged from a few hours to a few days. After developing the films the isolation of the hot particles was performed according to the relative blackening measurements of the digitalized images. As an example, Fig.1. shows an autoradiogram of an incidental filter sample. Details of the autoradiography is discussed elsewhere [1].

Electronmicroscopy

After isolation of fragments, in some cases (in co-operation with KFKI) scanning electronmicroscopic examinations were carried out to study the morphology and the elemental composition of the individual particles. By means of SEM the quantities of various corrosion products were determined. Usually the amount of uranium and transuranium elements did not reach the detection threshold in these fuel fragments.

Radioanalytical examinations

Radioanalytical examinations of hot particles identified by autoradiography were performed to determine the activity of the non-volatile transuranium elements and uranium. After a radiochemical separation procedure using di-pentyl-pentyl phosphonate extractant the activity of the alpha emitting Pu, Am/Cm and in some cases U isotopes were determined. Details of the procedure are discussed in paper [3]. In Fig.2. the flowchart of the radiochemical separation procedure is shown. The sources for the alpha spectrometry were made by micro-co-precipitation. The spectra were recorded with a multichannel analyzer using semiconductor detector. Based on the alpha spectra activity concentrations and activity ratios of certain actinides were determined.

The activity ratios of the transuranium elements are related to the burnup of the faulty fuels. The burnup of the fuel particles taken from the primary water during reactor-shutdown and from the incidentally contaminated water were determined from the measured activity ratios of the $^{238}Pu/^{239,240}Pu$ using theoretically calculated $^{238}Pu/^{239,240}Pu$ activity ratio-burnup functions according to the calculations of Möller-Burmeister [4]. The burnup of the particles can be estimated most accurately based on the measured $^{238}Pu/^{239,240}Pu$ ratio, because the ratios of the $^{242}Cm/^{239,240}Pu$ and $^{244}Cm/^{239,240}Pu$ are more dependent on the operation conditions of the reactor (e.g. varies as a function of the boric acid concentration).

The alpha-activities of the hot particles were in a wide range. The hot particles originating from incidentally contaminated water had high alpha-activities. The activities of the Cm isotopes in the hot particles collected from the primary coolant during normal operational conditions (during reactor shutdowns) are usually lower by one or two orders of magnitude. The measured activities of the examined particles are detailed in [5].

The activity ratios of $^{238}Pu/^{239,240}Pu$ ranged between 0,46-1,40 in case of the particles originating from failed fuels. The estimated burnup values for these particles were between 12-21 GWd/tU. The burnup data of the particles ranged broadly and are different from the burnup data of the measured activity ratios of the solutions. In case of the particles originating from the primary water, the measured $^{244}Cm/^{239,240}Pu$ ratio in function of the measured $^{238}Pu/^{239,240}Pu$ is shown in Fig.2.

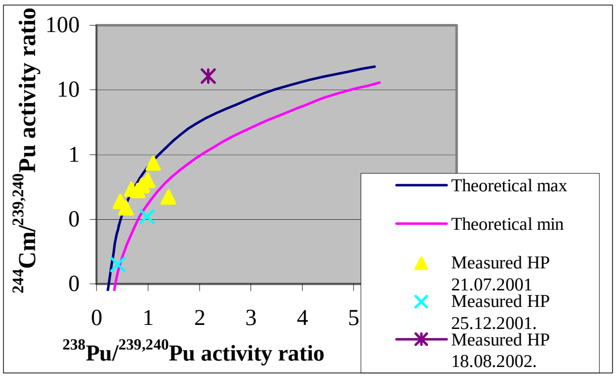

Figure 2. Measured activity ratios of hot particles originating from failed fuel elements from Unit 3

According to the previous measurements of bulk samples one defected fuel element was detected with macro failure, which was about 2-years old. It is not excluded that particles have been released from surface contamination.

The activity ratios of $^{238}Pu/^{239,240}Pu$ ranged between 0,16-6,78 in case of the particles originating from the incidentally contaminated water. The estimated burnup values for these particles were between 5-55 GWd/tU. The average burnup of the incidentally damaged 30 fuel assemblies was about 16GWd/tU. The calculated (theoretical) maximum burnup of the damaged elements was about 50GWd/tU.

In case of the particles originating from the incidentally damaged fuels, the measured $^{244}Cm/^{239,240}Pu$ ratio in function of the measured $^{238}Pu/^{239,240}Pu$ is shown in Fig.3.

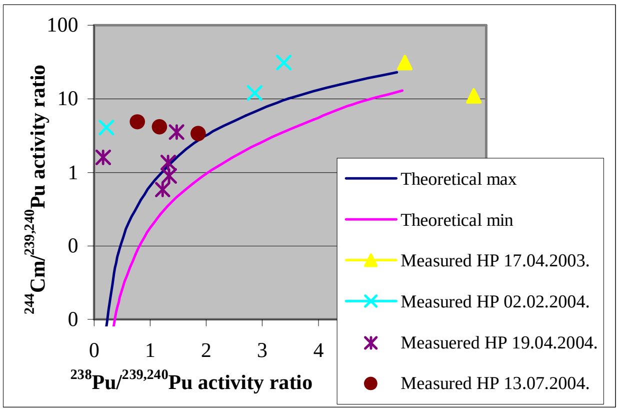

Figure 3. Measured activity ratios of hot particles originating from incidentally damaged fuel elements

The measured burnup of the particles were often higher than this average burnup (for the water as well as for the swipe samples) and in certain cases the burnup of the particles originating from the water samples was higher than the theoretical maximum burnup data. These high burnup particles were likely to have been released from the "rim-layer" of the pellets (from the outer region of the pellets having higher burnup than the average burnup of the pellets).

Conclusions

Micro- and radioanalytical methods were developed for the examination of hot particles originating from the primary circuit of NPP Paks.

Two types of fuel particles have been studied, i.e. particles released from failed fuels during reactor-shutdowns (during normal operation conditions) and those released from the incidentally damaged fuels at NPP Paks (April 2003). By measuring the activities of the transuranium nuclides the burnup of the particles as well as that of the defected fuel can be estimated. The examination of individual hot particles collected from primary water enables a more effective investigation of the fuel failures. The study of particles from incidentally damaged fuels shows that high burnup particles from the "rim" layer were also released.

Acknowledgement

I would like to express my gratitude to Nóra Vajda and Péter Zagyvai for their support, help and leadership of my PhD work, and also to Anna Pintér Csordás from KFKI AEKI for the SEM-EDX measurements.

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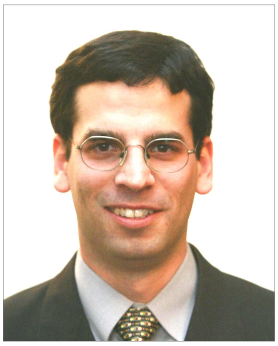
The 2004 awardee: Tamás Pázmándi

Curriculum Vitae of Tamás Pázmándi, the 2004 awardee



I am Tamás Pázmándi, the 2004 awardee. I graduated at the Budapest University of Technology and Economics as master in Engineering-Physics in 1999. In my diploma thesis I gave a comprehensive review of the heavy metal pollution in Hungary with an analysis of environmental samples. As part of my thesis I also developed new measurement techniques. With this work I won the Best Thesis Prize of the System International Foundation and the Ministry of Environmental Protection.

After the University I went to the Atomic Energy Research Institute as a PhD student. I defended my PhD in 2004. In my thesis I was dealing with space radiation dosimetry, developing a new combined device measuring the radiation weighting factor and the equivalent dose. Such systems can be applied in the dosimetry of the International Space Station and aircrew as well.

I graduated in 2002 at the Budapest University of Economic Sciences (second degree), dealing with online communication and the advertisements on the Internet.

I have more than 25 publications about heavy metal pollution in Hungary; space dosimetry; nuclear energy and sustainable development; PR in the nuclear field.

From 2001 to 2004 I was the president of the Hungarian Young Generation Network (YGN). Our purpose is to remove the misbelieves and fears arising in association with nuclear techniques and to answer the questions brought up by the Hungarian youth in this topic. YGN stands for the exchange of knowledge between the older and younger generations. It was also a great opportunity to make contacts with people from the nuclear community.

I am the vice-president of the Hungarian Nuclear Society since 2004.

In my free time I like to travel and I like the exciting books as well.

Space dosimetry with the application of 3D silicon telescope and Pille onboard TLD device

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Introduction

High intensity cosmic radiation above the ionosphere is weakened by the Earth's magnetosphere and the atmosphere, equivalent to 10 meter deep water. The dose rate in Low-Earth Orbit is hundred times higher than the natural radiation on Earth, and about ten times higher than at commercial aviation altitudes. Radiation exposures in space can exceed ten times the dose limits of workplaces, consequently radiation exposure could limit the flight time. Because of this, being aware of the radiation field and the resulting dose rate is essential, and hence monitoring is carried out on the basis of wide international cooperation [3].

Figure 1. Pille thermoluminescent dosimeter (TLD) system (reader, dosemeter, memory card)

Pille thermoluminescent dosimeter (TLD) system was developed in the KFKI Atomic Energy Research Institute (Fig. 1.) and it was used on several space vehicles during the last decades (Fig. 2.) [4]. The Pille-Tritel system is under development, the combined device will be applicable for the measurement of the absorbed dose and the radiation weighting factor which is a function of the linear energy transfer (LET) spectrum[5].

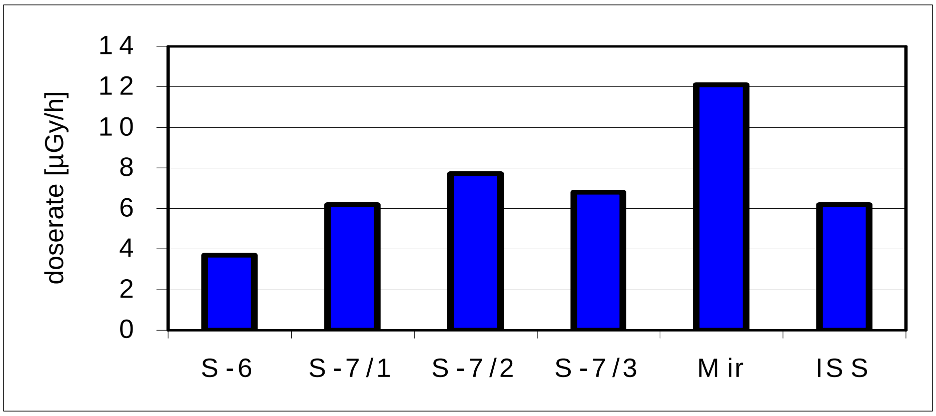

Figure 2. Dose rates measured by the Pille system (S-6 – Salyut-6, S-7 – Salyut-7)

Elements of the complex system

Since the space radiation mainly consists of charged heavy particles (protons and heavier particles) equivalent dose significantly differs from the absorbed dose. Combination of different measurements and calculations is required to characterise the radiation field in terms of dose equivalent.

Since recently used equipment is not fully suitable to measure both quantities simultaneously, a new combined device is under development. The elements of the complex system are the following (Fig. 3.):

- Absorbed dose is measured with the Pille TLD system[1] .
- Since efficiency of the TL dosemeter is a function of linear energy transfer (LET), values of the absorbed dose should be corrected.
- The basic quantity for radiation protection purposes is the equivalent dose, which is obtained by the multiplication of the absorbed dose by the radiation weighting factor (w_R), which is a function of the LET value of the concerned radiation. The LET value of the space radiation shows wide range distribution between 0.3 and 200 keV/µm. There are several methods to determine the LET, in this project silicon detector telescope is used.

– The effective dose can be determined if the method is complemented with phantom-measurement,
– Effect of the secondary neutrons should be taken into consideration separately to obtain the total dose.

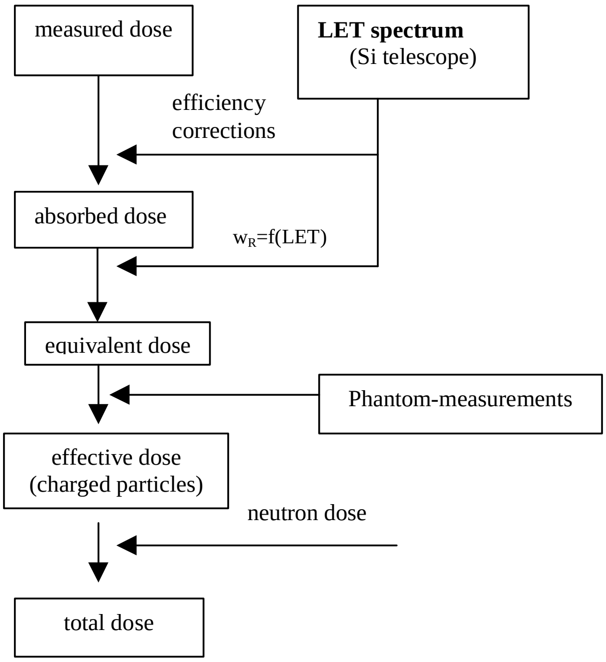

Figure 3. Elements of the complex system

In the combined device the Pille TLD system will be used to determine the absorbed dose and the silicon detector telescope to measure the LET spectra[2]. Advantages of the Pille system is the availability for measurement at several locations at the same time, hence could be used for dosimetric mapping and personal dosimetry as well.

Evaluation software converts the LET spectrum to an average radiation weighting factor (w_R) and the TL dosemeter correction factor is applied to calculate the absorbed dose. The final output of the system – including ground evaluation as well – will be the equivalent dose on board International Space Station.

If LET-spectra of the radiation field is determined with the silicon detector telescopes, then the corrected TLD measurements can be used for personal dosimetry of the International Space Station.

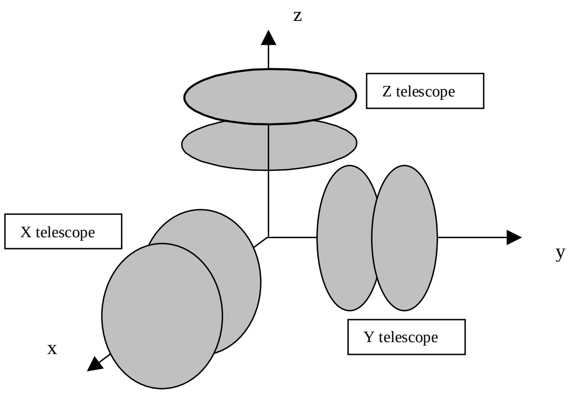

Figure 4a. Set-up of the 3-dimensional telescope

Silicon telescope

The 3-dimensional silicon telescope called Tritel is under development. It is based on six identical passivated implanted planar silicon (PIPS) detectors and designed to measure the energy deposit of charged particles (Fig. 4 a, b). All the three axes of the Tritel telescope consist of two parallel Si detectors, a measuring and a gating detector. Each of these detectors are connected to a charge sensitive preamplifier. After preamplification and pulse shaping the pulses are amplified and sent to a coincidence circuit in case of each axes. The pulses of the measuring detector and the signal of the coincidence circuit are fed to a peak detector. The output of each peak detectors are sent to a flash amplitude analyser. This version will mostly exclude the highly anisotropic sensitivity of the recently used silicon telescopes.

The three pair silicon detectors are connected as AND gate in coincidence. However, the instrument can not determine the arrival direction of the individual particles. The instrument cannot provide the primary energy spectrum only the energy deposit of charged particles including spallation products. Both detectors have a thickness of 315 µm and a sensitive area of 693 mm^2.

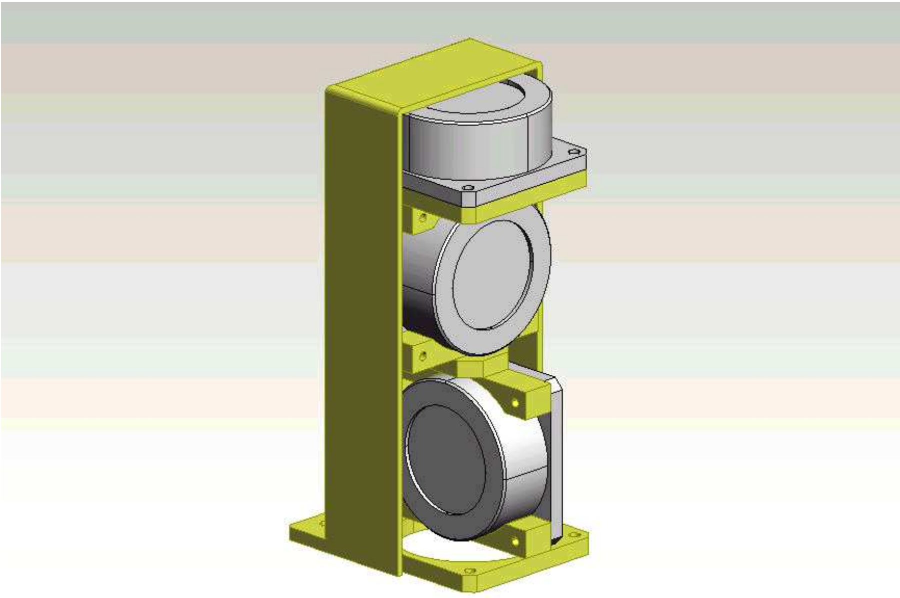

Figure 4b. TRITEL 3D silicon detector telescope

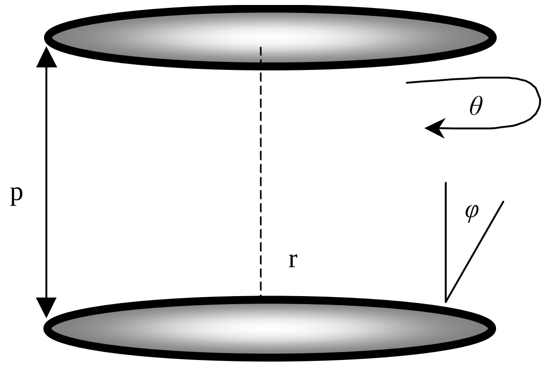

Figure 5. Parameters of the silicon telescope

Geometry parameters of the silicon detector telescope

The main parameters of the telescope can be seen on Fig. 5, where r means the radius of the crystals, p is the distance between the crystals and q is the quotient; φ and θ are the angles as it can be seen on Fig 5.

$$q=p/r$$

There are two important parameters depending on the geometry:

– efficiency (directly proportional to the number of events measured by the detector),
– precision of the energy loss measurement (i.e. ratio of deposited energy for minimum and maximum angles of registration – E_{min}/E_{max}).

If q is lower, then the efficiency is higher but in this case the E_{min}/E_{max} is less, since the possible way in the detector is longer and hence the absorbed energy is more. The two parameters as a function of q can be seen on Fig. 6.

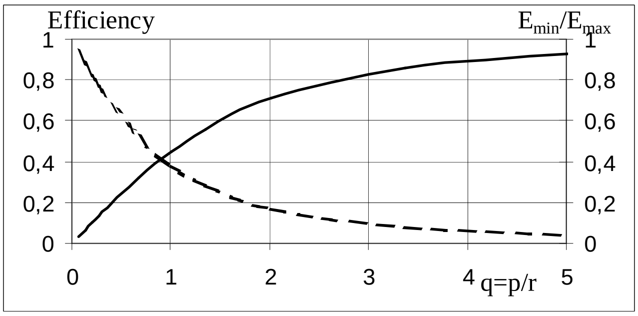

Figure 6. Efficiency and precision (-- efficiency — E_{min}/E_{max})

There is another relevant standpoint in the case of 3-dimensional telescope: difference of the efficiency at various orientation should not be too high. The efficiency for 3-dimensional silicon detector telescope is delineated on Fig 7.

Inverse algorithm

A new method (inverse algorithm) was elaborated for calculating the LET spectra of the radiation field from the measured data. Parameters of the inverse algorithm, restoring the characteristics of the field from the measured spectra were defined. Protons, alpha particles, C and Fe ions were used for the calculations, minimal energy of particles passing through the 300 μm thick silicon detector could be seen in Table 1.

Type of the particle	E_{min} (MeV)
H	6,5
He	27,5
C	130
Fe	1200

Table 1. Minimal energy of particles passing through 300 μm thick silicon detector

Changing of the LET of the charged particles in the detector and the effect of the particles stopping in the detector were taken into consideration. The algorithm was verified with numerical databases and measured spectra. Parameters of the inverse algorithm were analyzed.

We used 5% uncertainty in the input spectrum to analyze the accuracy of the method. Although the variance of the result was about 10% in some special cases, we established, that the effect of this for the radiation weighting factor is irrelevant (less then 3%).

It was established that if definite answer exists, then the algorithm could determine it and accuracy of the results is sufficient. However if there is any inconsistency in the input data, the result will be wrong or pointless. It could be used for verification of the input data as well.

Conclusions

Accurate dose measurement as well as the measurement of the ratio of low to high LET dose components will become increasingly important in forthcoming years during the assembly of large orbital stations.

The described devices would provide the information for absorbed dose, LET spectrum, quality factor and equivalent dose as well. The 3-dimensional silicon telescope should be the first such device used for measuring the dose the astronauts are subjected to.

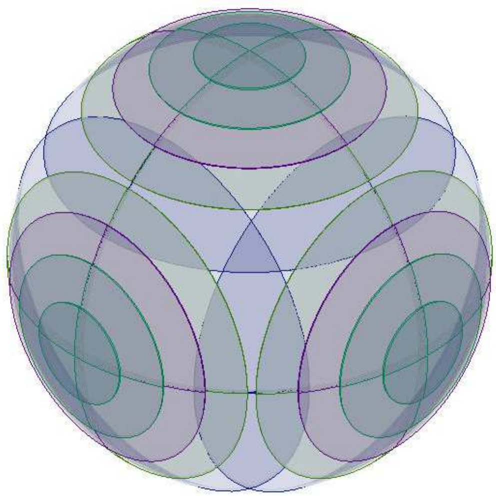

Figure 7. Efficiency in case of 3D telescope

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The 2005 awardee: Rita Dóczi

Curriculum Vitae of Rita Dóczi, the 2005 awardee

I was born in Tatabánya, Hungary on the 15th of December, 1970. I did my final exams with excellent results at Eötvös József Gimnázium (Grammar School), where I became fond of physics and current Hungarian literature. (If I had studied just literature at university I could not have considered the honor of applying for Fermi Prize.) I graduated from the University of Debrecen (then: Kossuth Lajos University) with an eminent diploma, then I took part in a Ph.D. training in nuclear physics under the supervision of Prof. Julius Csikai. I defended my thesis in 1998, under the title: "Differential and Integral Cross-sections of Neutron-Induced Nuclear Reactions." I was qualified "Summa Cum Laude". I also have a diploma as English-Hungarian translator in physics.

I performed my experiments in the Debrecen University Institute of Experimental Physics, ATOMKI (Institute of Nuclear Research of the Hungarian Academy of Sciences) and in the Jülich Institute of Nuclear Chemistry, Germany, applying various types of accelerators, detectors and radiochemical separation techniques. So far I have worked or have had scholarships at the institutions mentioned above. I still have neutron physics as a field of research, I have been awarded several prizes and scholarships such as "Köztársasági", Pro Regione, TEMPUS, Universitas, the prize of the Academic Committee of Debrecen, OTKA post-doc scholarship, Bolyai scholarship.

I did nuclear chemistry in Germany and environmental studies in Belgium within the frame of a post-graduate training. My works have been published in several international conferences and journals. I took part in the validation of the reliability of the data offered by international nuclear databanks, and discussions of IAEA on the demining project. I also work in the OECD-NEA WPEC subgroup 19. (measurements of activation cross-sections). I have been participant of several OTKA (Hungarian Scientific Research Fund) and IAEA research contracts. We are cooperating with Japanese, Belgian, German and Egyptian researchers. I am co-author of the 5-volumed Handbook of Nuclear Chemistry. I am the happy mother of 43 publications 21 lectures and two lovely and clever children.

Applications of the Fermi's albedo principle for the determination of H-contents

RITA DÓCZI

The reflection property of a sample can be characterized by the albedo of thermal neutrons. The principle of the albedo based on the measurement of the activity of a thin foil with and without reflector was introduced by Amaldi and Fermi (1936). This method was generalized by Csikai (1987) for two media of different neutron diffusion properties which is the most common arrangement in practice. This technique was also used for the determination of the hydrogen content in different compounds and mixtures. Quality control is applied broadly including the materials used in agriculture, forestry, fibers, fossil fuels and those related to environmental pollution produced by the coal-fired power plants. Studies on nuclear energy materials are indispensable for the selection of proper structural components.

A new method based on the epithermal neutron activation has been developed for bulk hydrogen analysis. The sensitivity of this activation method for typical sample dimensions is higher by a factor of ~100 than the neutron reflection technique.

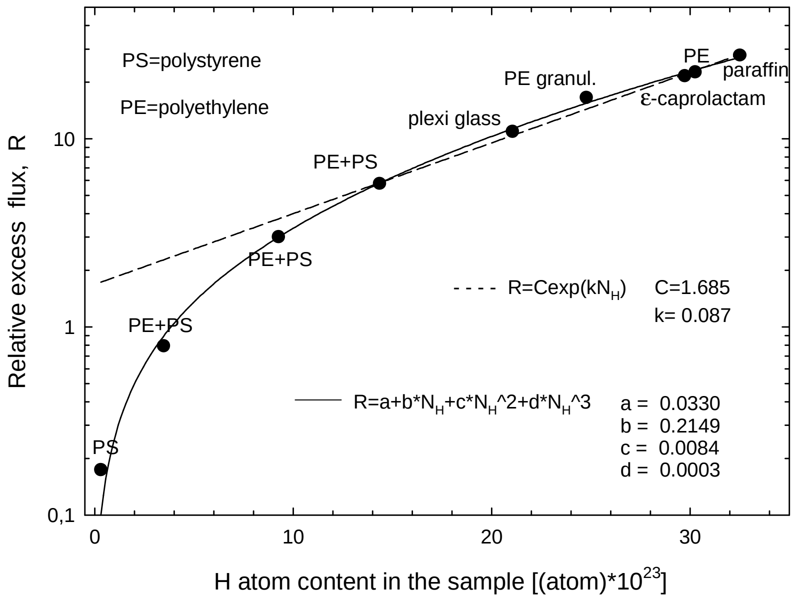

Figure 1. Average excess neutron flux vs. hydrogen content measured in a graphite-pile moderator by Dy foils using a Cd box

Epithermal neutrons produced in hydrogenous and graphite moderators by simple radioactive Am-Be, Pu-Be, ^{252}Cf sources can be used for bulk hydrogen analysis if the sample is placed in a Cd box. The relative excess flux of neutrons ($R = (\langle\Phi\rangle - \langle\Phi_0\rangle)/\langle\Phi_0\rangle$ measured with $\langle\Phi\rangle$ and without $\langle\Phi_0\rangle$ a sample) thermalized by the reflector materials increases exponentially with the total hydrogen content. Analytical expressions are given for the description of the excess flux of thermalized neutrons as a function of hydrogen content of different samples (see Fig.1). The axial flux distributions of neutrons inside the samples (which is needed to determine the the average flux $\langle\Phi\rangle$) can be approximated by a second order polynomial, therefore, it is enough to place the activation detector foils (In, Dy) in three points of the sample, e.g. at the two edges and the center, in order to determine the average flux density and through it the hydrogen content.

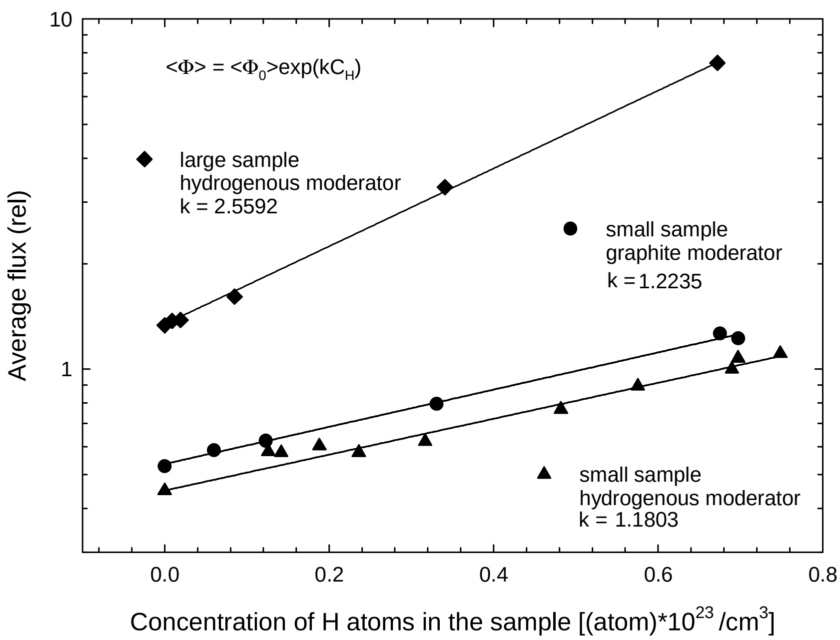

Figure.2. Averaged flux value as a function of hydrogen concentration of the sample measured by In foils

The detection limit of this activation method is ~ (0.05 ± 0.01)g hydrogen using 10-10 min periods for irradiation and measurement with about 10^6n/s source yield. Both the hydrogenous and the graphite moderators are recommended for the analysis, however, the latter has definite advantages for bulky samples because of the almost constant flux values at large distances (30-40 cm) around a point-like source.

Further investigations showed that this epithermal neutron activation method can be used for hydrogen analysis of larger (kg, liter) saples as well. Definite correlations were found between both the average and excess flux values vs. the hydrogen concentrations as well as the total hydrogen contents, respectively, of the samples. The average flux density depends exponentially on the hydrogen concentration. The large sample has a special adventage if the determination of the hydrogen contentration is in question (see Fig. 2).

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The 2007 awardee: Gergő Pokol

Curriculum Vitae of Gergő Pokol, the 2007 awardee

I'm Gergő Pokol, the 2007 awardee. I graduated at the Institute of Nuclear Techniques, Budapest University of Technology and Economics (BME NTI) as master in Engineering-Physics in 2004. During my undergraduate years, I engaged in the analysis of signals from fusion plasma experiments with modern signals processing methods. After defending my Master's thesis in 2004, I attained a state grant to continue my studies on the field of experimental fusion plasma physics as a PhD student at the BME NTI.

I had many publications on the analysis of signals from different plasma diagnostics of the Wendelstein 7-AS stellarator and I am still continuing to do research in this direction. An interesting episode of my research was the application of the signals processing methods that were developed for plasma diagnostics on the acoustic signals of the Advanced Loose Parts Monitoring System of the Paks NPP.

I have spent the autumn of 2005 at the Chalmers University of Technology, Gothenburg, Sweden, where I investigated a problem associated with the next generation of fusion plasma devices (like ITER), with the tools of the kinetic theory of plasmas. After a number of publications and another semester of studies in Sweden, I have been awarded the Swedish scientific degree "Licentiate of Engineering" in 2007.

Besides doing research tasks, I take part in the education of undergraduate engineering-physicist students by lecturing and supervising.

In the time interval of 2004-2007, I was the secretary of the Fusion Section of the Hungarian Nuclear Society. Since 2006, I am the EFDA Remote Participation Contact Person for BME NTI. I regularly take part in the organization of seminars and conferences.

I spend most of my free time with my wife and daughter doing sports or just having fun together.

Transient waves is fusion plasmas

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INSTITUTE OF NUCLEAR TECHNIQUES, BUDAPEST UNIVERSITY OF TECHNOLOGY AND ECONOMICS

Introduction

It has been known for quite a long time now, that is a huge amount of energy released during the fusion of light atomic nuclei, and the parameters of these fusion reactions have also been measured decades ago. Practical application of fusion energy production is, however, still not possible due to the simple reason that the positively charged nuclei repel each other, and so large energy collisions are necessary for fusion reactions. As it can be derived from the energy dependence of the fusion reaction cross-sections, the criterion for fusion energy production requires the confinement of a sufficiently dense material for sufficiently long times at a temperature of about 100 million °C (Lawson criterion) [1].

At the temperature required for fusion, matter is in the plasma state, the greatest challenge of fusion research is the confinement of this substance. The most promising concept of fusion plasma confinement uses magnetic fields. We can hold a relatively low density (~10^{20} m^{-3}) plasma with a strong (~5 T), torus shaped magnetic field for relatively long time (>1 s).

During its 50 years of evolution, two really successful toroidal magnetic confinement concepts were developed: the tokamak and the stellarator (Figure 1). Both concepts utilize a toroidally closed magnetic field structure, this way the charged plasma particles moving along field lines cannot escape form the device. In order to hold the plasma in place, a helical twisting of the magnetic field lines is necessary and this is the point where the two concepts differ. In a stellarator the magnetic configuration is determined by the coils positioned outside the plasma, while in a tokamak a large toroidal plasma current (1-10 MA) is driven, providing the twist for the magnetic field lines.

Of course, in reality the structure of the devices is not as simple as shown in Figure 1. Figure 2 shows the plans of the largest tokamak (ITER) and the largest stellarator (Wendelstein 7-X) being built today. ITER is built in Cadarache, France in a worldwide cooperation [2], while Wendelstein 7-X is built by Germany and EU in Greifswald [3].

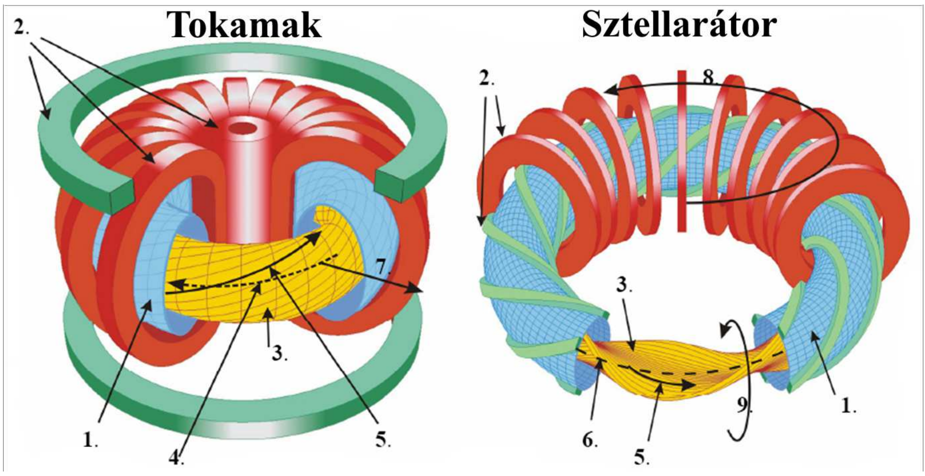

Figure 1: Concept of the tokamak and the stellarator: 1. Vacuum chamber, 2. Toroidal and helical field coils, 3. Plasma, 4. Plasma current, 5. Magnetic field line, 6. Magnetic axis, 7. Radial direction, 8. Toroidal direction, 9. Poloidal direction

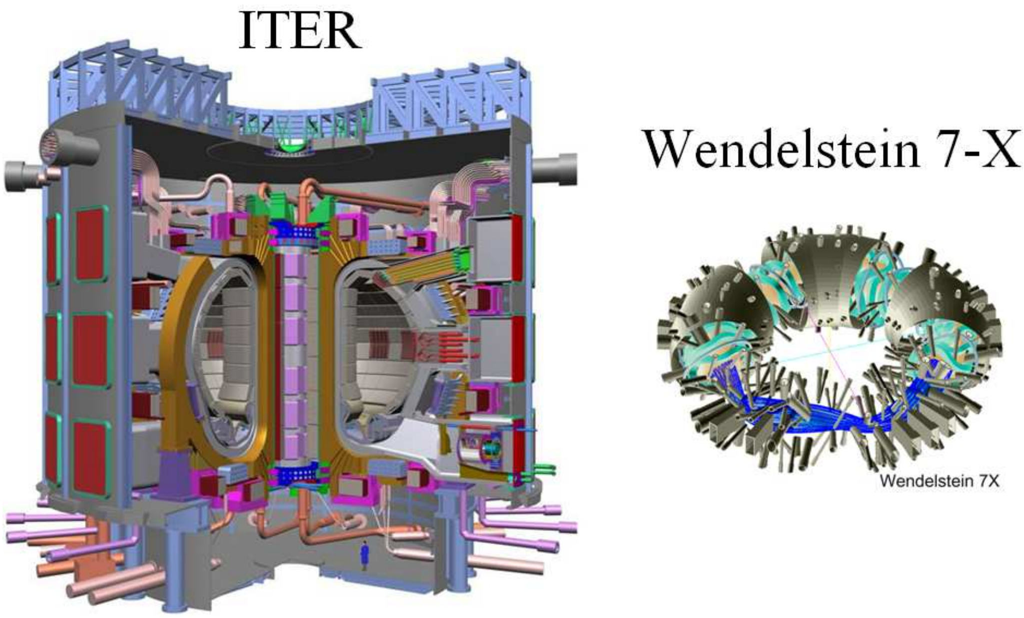

Figure 2: Main components of the ITER tokamak and the Wendelstein 7-X stellarator

Transient MHD modes

The first topic of this paper is the mostly experimental analysis of phenomena observed in the plasma of the Wendelstein 7-AS (W7-AS) stellarator, and so it is more relevant from the point of view of the future performance of Wendelstein 7-X.

Motivation: earlier observations

It has been observed in both tokamak and stellarator type devices that the transport coefficients change significantly in the proximity of rational surfaces, where the magnetic field lines close into themselves after a few turns around the torus [4,5]. In these surfaces the rotational transform (iota), which is the ratio of the poloidal and toroidal turns of the filed lines, is a rational number. The W7-AS stellarator is exceptionally suitable for studying this phenomenon, as it has an almost flat iota profile, so the presence of a rational surface causes a change in the global confinement properties. This is in contrast to tokamaks, where the iota profile is steep, and the effect of a rational szrface is localized. The physics of the confinement transitions observed at rational surfaces is still not understood, but there are indications that transient transport events – called ELM-like modes at W7-AS [6] – have their role in it. ELM-like modes are accompanied by transient magneto-hydrodynamic (MHD) modes. These are coherent, few periods long bursts in the density and magnetic signals [7]. I have analysed the spatio-temporal structure of these modes and their link to transport processes.

Experimental results

I have conducted the analysis of the structure of the transient MHD modes and their connection to the ELM-like events by using signal processing methods based on contimuous time-frequency transforms. These tharsforms have two classes: the short-time Fourier transform (STFT), and the analytical continuous wavelet transform (CWT). The mathematical apparatus is not described in this paper, but rather can be found in the referenced works [8,9].

Figure 3 shows a spectrogram of a magnetic fluctuation signal calculated by STFT, and showing the energy-density distribution on the time-frequency plane plotted using the colour scale located besides the plot. It can be observed that the short bursts appear at characteristic frequencies – in this particular discharge at 85 kHz, 60 kHz, 45 kHz and 25 kHz. Energy-density distributions were also subject to further processing [10,11].

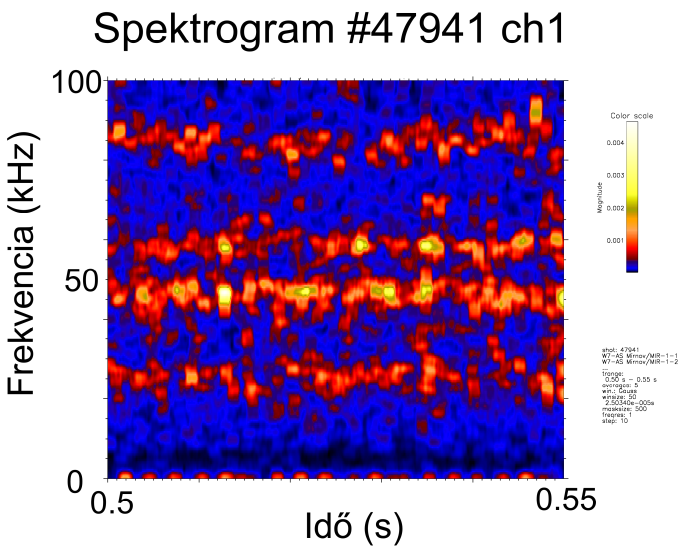

Figure 3: Spectrogram of a magnetic fluctuation signal of the W7-AS stellarator

In most cases we have a number of probes observing the same event, so we may attempt to reconstruct the spatial structure of the detected perturbations. For global modes, like the transient MHD modes this means the determination of the toroidal and poloidal mode numbers. The relative phase of the signals of probe pairs can be determined form the time-frequency transforms, and from all the relative phases the most probable mode numbers can be estimated [12]. Figure 4 shows the mode numbers reconstructed from a set of 16 probes positioned around a poloidal cross-section of the plasma for the same time interval as Figure 3. Sign of a mode number marks the rotation direction (positive for electron diamagnetic drift direction). White colour marks the regions which showed no sign of and determined mode number. It can be derived that around 25 and 45 kHz the +2 mode number dominates, while +3 mode number events appear typically at around 10 kHz. Other mode numbers are scattered around the plot and are most probably random structures.

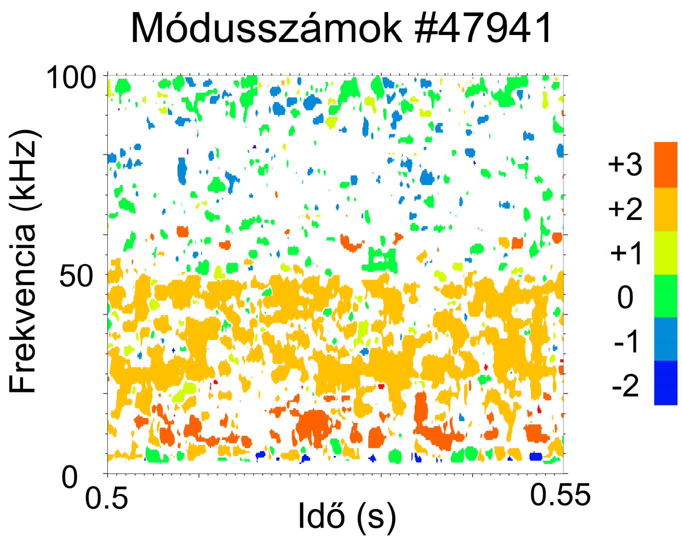

Figure 4: Mode numbers of transient MHD modes of the W7-AS stellarator reconstructed from magnetic fluctuation signals

Different discharges show different frequency mode numbers, but the general conclusion can be made that typically we have low mode number modes in the frequency range 10-100 kHz and lifetime of a few oscillations.

Possible theoretical models

Our analysis revealed that the amplitude of the transient MHD modes correlate with the temperature and density changes accompanying ELM-like events [13,14]. Ths indicates a causality link between the plasma waves and transient transport phenomena. One possibility is that a plasma wave is destabilized by the critical gradient of a plasma parameter, and it drives transport through nonlinear processes, or alternatively, the wave might be caused by the MHD perturbation of the transient transport event [12]. Decision is to be based on further detailed modelling.

Runaway electrons and whistler waves

The second topic covered in this paper is mode theoretical I nature: it discusses the interaction of runaway electrons showing non-Maxwellian velocity distribution and whistler waves.

Motivation: experimental observations

In major tokamak disruptions the plasma confinement is suddenly lost, but tha strong toroidal current cannot just vanish due to the self-inductance phenomenon. The continuing plasma current is only possible in the highly resistive cold plasma if a strong toroidal field rises. In certain conditions this electric filed accelerates a significant fraction of the plasma electrons to relativistic energy (~20 MeV). This runaway electron beam can seriously damage the device so it is to be avoided. The number of runaway electrons varies greatly in different disruptions [15,16], which might be explained by the interaction of runaway electrons with a plasma wave.

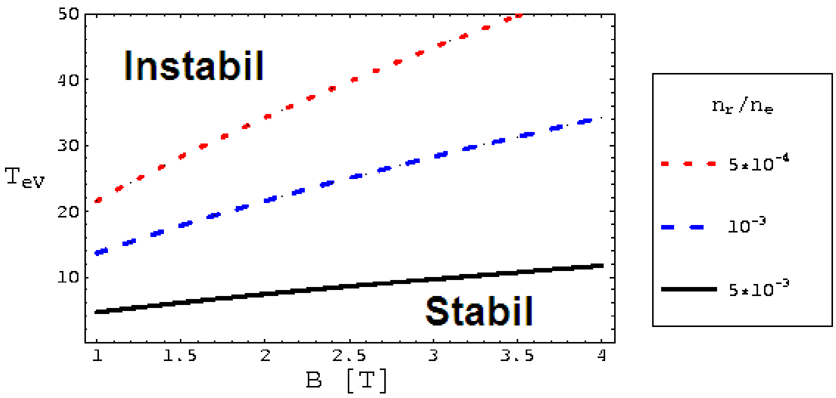

Figure 5: Stability region of the whistler wave on the magnetic field (B) and post-disruption temperature (T_{eV}) parameter plane for different runaway fractions (n_r/n_e) and pure deuterium plasma

Wave-particle interaction

The distribution function of runaway electrons calculated from the relativistic Boltzmann equation, shows a large velocity anisotropy: electrons practically move in one direction [17]. This anisotropy can destabilize the plasma waves resonant to the electrons with a given momentum.

The wave is unstable if the growth rate resulting from the runaway electrons is larger than the damping term.

Figure 5 shows the stability region of the whistler wave having the most unstable wave number for different runaway electron fractions [17]. The wave is more unstable for lower magnetic fields which shows good agreement with experimental observations [15,16].

Following a phase of linear growth, the wave starts to interact with the runaway electrons. Figure 6 shows the results of a numerical calculation of this interaction using the quasi-linear model [18]. Our calculations indicate that the destabilization of the whistler wave may indeed be responsible for the observed variation of the number of runaway electrons.

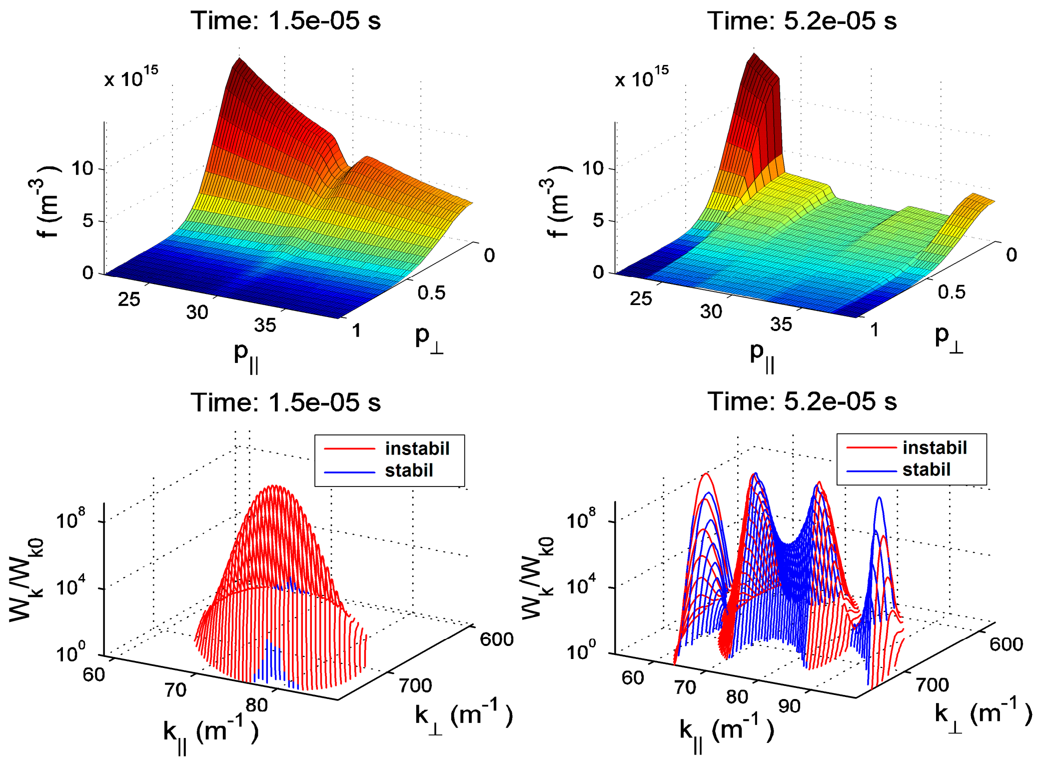

Figure 6: Quasi-linear interaction of the whistler wave and runaway electrons: Upper figures show the distribution function of the runaway electrons as a function of electron inertia parallel and perpendicular to the magnetic field for two time instances. Lower figures show the spectral energy of the whistler wave as a function of wave vector components parallel and perpendicular to the magnetic field for the same time instances.

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The 2008 awardee: Árpád Farkas

Curriculum Vitae of Árpád Farkas, the 2008 awardee

I'm Árpád Farkas, the 2008 awardee. I graduated in Physics from *Babes-Bolyai University* of Cluj Napoca in 1996. During my undergraduate years my research efforts were focused on the study of crystal lattices by different X ray techniques. I graduated as MSc in Solid State Physics from *Louis Pasteur University*, Strasbourg and *Babes-Bolyai University*, Cluj Napoca in 1999. During my master studies I engaged in the field of development of new materials for magnetic information storage and retrieval, and their analysis by NMR techniques. The NMR investigations were performed in the frame of a *SOCRATES/ERASMUS* grant at the *IPCMS* (Institut de Physique et Chimie des Materiaux) Strasbourg.

I have been working for *Hungarian Academy of Sciences KFKI Atomic Energy Research Institute* of Budapest as a research scientist since 2001. My research topic is related to numerical modelling of health effects of low doses of ionizing radiations, with special emphasis on the radiation protection aspects.

I got my PhD degree in the same topic from *Eötvös Loránd University* of Budapest in 2008. A significant part of the related work was completed at *University of Salzburg*, the longest stay being a six month fellowship in the frame of *Euratom Programme* of the *EU 6th Framework Programme* in 2005. In the same year I was awarded the *Junior Prize of the Hungarian Academy of Sciences.* During my PhD studies I attended 16 academic conferences, and 16 out of my 72 scholarly publications were published in international peer reviewed journals.

I took part in 5 Hungarian, 4 European Union and 2 Austrian-Hungarian bilateral projects in the topic of radiation physics, radiation biology and radiation protection.

I reviewed scientific manuscripts for the *Journal of Aerosol Science*, *Journal of Aerosol Medicine* and *International Journal for Numerical Methods in Fluids* journals.

At present, I am a member of *The Aerosol Society* (United Kingdom) and of the *EURADOS the European Radiation Dosimetry Group* professional societies.

Numerical modelling of transport, airway deposition and health effects of radon decay products

ÁRPÁD FARKAS
HUNGARIAN ACADEMY OF SCIENCES KFKI ATOMIC ENERGY RESEARCH INSTITUTE

Introduction

The understanding of health effects of low dose ionizing radiation seems to be one of the most challenging issues of current radiation protection, radiation biophysics and radiation biology. Epidemiological studies of atomic bomb survivors and former uranium miners revealed that there was a strong correlation between enhanced lung cancer incidences, leukemia and other health disorders and high levels of radiation(1,2). However, due to the different exposure conditions, direct extrapolation of A-bomb and miner data to low doses is not suitable(3). At the same time, in spite of sophisticated statistical analysis, residential radon studies yielded limited epidemiological evidence at low doses. Furthermore, due to the difficulties in measuring the true response at very low doses, experimental radiation carcinogenesis has not yet provided a plausible dose-effect relationship in the low dose range(4). This suggests that the understanding of mechanisms of action of radiation and the cellular changes which lead to malignancy is increasingly important in biological risk estimation. Hence, the development of biophysical mechanisms based complex risk models seems to be a promising avenue. However, mechanistic models require exact microdosimetric quantities. Most of current lung dosimetry models are based on some strongly simplifying assumptions, like straight cylindrical airways and uniform radon progeny deposition. In reality, the tracheobronchial tree is a system of asymmetric, repeatedly branching tubes and the site specificity of particle deposition has been shown both experimentally(5) and by CFD methods(6, 10-14). However, the systematic use of CFD techniques as a tool in microdosimetry and cancer research is not fully employed. Thus, the objective of this study was to develop a computational fluid and particle dynamics based model, capable to characterise the local burden of epithelial cells. This model was applied to exposure conditions characteristic of homes and mines.

Methods

A computational fluid and particle dynamics based numerical model was developed and validated to characterize the local burdens of the deposited short-lived radon progenies in the bronchial airways. The main steps of the model construction were the generation of the three-dimensional bronchial airway geometry, the construction of a mathematical mesh, the implementation of the flow field and particle trajectory computing numerical schemes, and the development of some post-processing tools.

The model geometry incorporated the main, lobar, segmental and subsegmental bronchi of the central airways, where most of the radon induced neoplastic and preneoplastic lesions have been found. The air flow field and radon progeny deposition computations were performed for breathing and exposure conditions characteristic of homes and uranium mines. In both cases, 10^7 inhaled radioactive aerosol particles were tracked. The extrathoracic deposition efficiencies were computed by the "stochastic lung model" of Koblinger and Hofmann[(7)]. In order to quantify the local deposition, deposition enhancement factors (defined as the ratio of local to the average deposition density) were computed. Local radiation burden of attached and unattached radon daughters was characterized by potential alpha-energy enhancement factors, defined as the ratio of local to the average potential alpha-energy densities. By potential alpha-energy is meant the kinetic enrgy of alpha-particles emitted by the short-lived radon daughters. Thus, ^{218}Po represents a potential alpha-energy of 13.68 MeV, to ^{214}Pb and ^{218}Bi isotopes being assigned a potential alpha-energy of 7.68 MeV. The enhancement factors were computed by scanning along the whole tracheobronchial surface with a pre-specified surface area. The patch size was chosen to be 1.4×10^{-7} m^2, covering the surface of about one thousand epithelial cells. The breathing and exposure conditions characteristic of homes and mines were taken from the published literature[(2, 8, 9)].

Results and discussion

In a mine environment, at an airflow rate of 50 l/min for nose breathing, the stochastic deposition computations yielded 3.3 and 82% extrathoracic deposition efficiencies for the attached and unattached radon progenies respectively. The corresponding values at 18 l/min flow rate, characteristic of homes, were 4.37 for the attached and 89.8 % for molecular fractions.

Trajectories of the particles unfiltered by the upper airways were simulated by FLUENT, which is a commercially available CFD code. The tracheobronchial deposition distribution of the attached and unattached radon daughters proved to be highly inhomogeneous both for mine and home conditions (Figure 1).

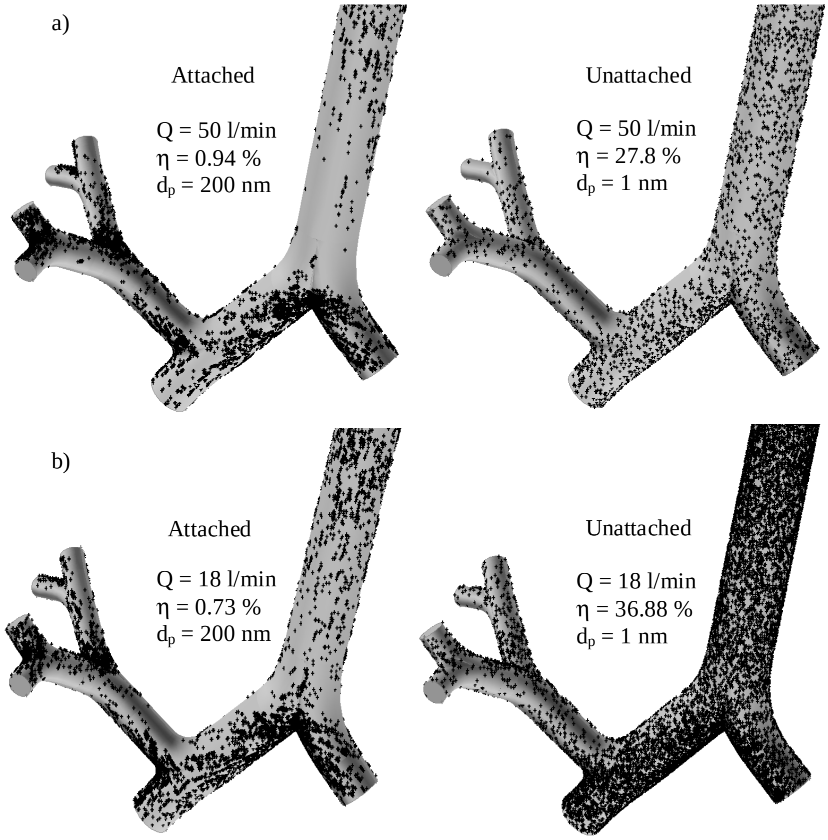

Figure 1. Inspiratory tracheobronchial deposition patterns of attached (^{218}Po, ^{214}Pb and ^{214}Bi/^{214}Po) and unattached (^{218}Po) radon progenies in a) mines and b) homes. Q - tracheal flow rate; η - deposition efficiency; d_p – particle diameter.

As Figure 1 illustrates, the inhomogeneity was more evident for the attached fraction due to the impaction mechanism. The molecular diffusion caused a 7.6 times lower maximum deposition enhancement factor of the unattached radon progenies than of attached ones in mines. The same factor for homes was 17.8 (figure 2).

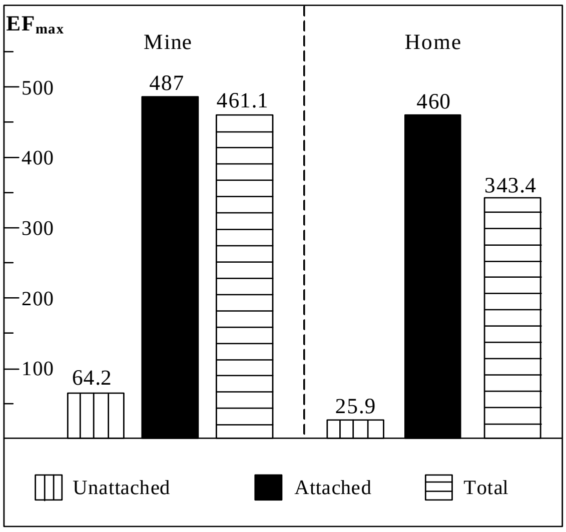

Figure 2. Maximum deposition enhancement factors (EF_{max}) of short-lived attached and unattached radon progenies for exposure conditions characteristic of uranium mines (left panel) and homes (right panel). EF_{max} is the maximum value of the enhancement factors, characteristic of the patch with the highest deposition density.

As the different short-lived radon progenies will potentially transfer different amount of energy to the epithelium for the exact quantification of radiation burdens not only the number of radionuclides, but also the potential alpha-energy of the individual isotopes has to be taken into account. For the present calculations, the ten million inhaled particles lead to about 7×10^7 MeV total tracheobronchial energy deposition in mines and 6.7×10^7 MeV in home environments. This indicates that assuming uniform airway deposition, the same macroscopic dose leads to very similar average burdens. However, radionuclide deposition is not uniform and exact risk estimation can only be performed by the quantification of local burdens. For this purpose, alpha-energy enhancement factors were computed. The maximum potential alpha-energy enhancement factor values were 480.5 and 325.82 for mines and homes, respectively. This result shows that some cell clusters may receive high doses even at low macroscopic doses. Another finding is that for the same macroscopic dose, the most exposed cell clusters receive different energies in different exposure conditions. Therefore, in accordance with the published literature[(3)], direct extrapolation of miner data to the general public is not appropriate. Since the detrimental health effects depend mainly on the exposure in the hot spots, exact microdosimetric quantities and correct dose-effect curves cannot be modelled without computing the distribution of deposition and potential alpha-energies.

Conclusions

This study showed that computational fluid and particle dynamics-based numerical models can be a powerful tool in the characterization of local radiation burdens. By the development and application of such a model, the inhomogeneity of the bronchial radionuclide deposition can be quantified. Comparison of local burdens computed for exposure conditions characteristic of homes and uranium mines revealed that the site specificity of radionuclide deposition can imply different burdens at the same macroscopic dose, but for different exposure conditions. Current results can also serve as input data for future microdosimetry and risk assessment computations. The integration of the present CFD model with a hit probability computing model and the state-vector model of carcinogenesis leads to a mechanistic complex risk model characterizing the effects of inhaled radon progenies.

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The 2009 awardee: Mihály Molnár

Curriculum Vitae of Mihály Molnár, the 2009 awardee

Name: Dr. Mihály Molnár

Date of birth: 04.04.1974.

Nationality: Hungarian

Civil status: married

Education: Master of Science in Physics and Chemistry, PhD. in Physics

Languages: English, intermediate level, reading and writing

Membership of professional bodies: Member of Society of Hungarian Chemists since 2000**.** Member of Roland Eötvös Physical Society since 2006.

Present position:

Research Fellow in Institute of Nuclear Research of Hungarian Academy of Science (INR/HAS) since 01/2003. Assistant head of Laboratory of Environmental Studies of the INR/HAS since 10/2004. Assistant head of Department of Earth and Environmental Sciences of the INR/HAS since 07/2005.

Employment or training in a foreign country:

Training on applications of stable-isotope measurements in environmental studies in Bari, Italy, supported by COST-621 programme: Groundwater Management of Coastal Karstic Aquifers. (2 weeks).

Training on sample preparation for AMS ^{14}C measurements in the Lab of Oxford Radiocarbon Accelerator Unit, Oxford, England (2 weeks).

Fulbright Scholar at NSF-Arizona AMS Facility, Tucson, USA. Project title “Study of sample preparation techniques used in AMS radiocarbon dating” (3 months)..

Professional Experience Record:

Ph.D. student, September 1997 – August 2000, Joint Department of University of Debrecen and Institute of Nuclear Research of the Hungarian Academy of Science, 4026 Debrecen, Bem tér 18/c. Radiocarbon measurements by beta counting (dating and environmental research also), LSC applications, sample preparation technique development for environmental studies, study of radioactive wastes.

Research Assistant, September 2000 - December 2003, Laboratory of Environmental Studies, Institute of Nuclear Research of the Hungarian Academy of Science, 4026 Debrecen, Bem tér 18/c. Radiocarbon measurements by beta counting (dating and environmental research also), LSC applications, sample preparation technique development for environmental studies, study of radioactive wastes. Gas analytical measurements by quadrupole mass spectrometer.

Research Fellow, from January 2004, Laboratory of Environmental Studies, Institute of Nuclear Research of the Hungarian Academy of Science, 4026 Debrecen, Bem tér 18/c. Radiocarbon dating of environmental and archaeological samples (beta counting by GPC and LSC), ^{3}H, ^{36}Cl, ^{99}Tc and ^{90}Sr measurement by LSC. Development of sample preparation technique for ^{14}C AMS measurements and beta counting, mass spectrometry applications (IRMS and QMS) in environmental studies. Development and installation of monitoring stations for airborne ^{14}C. ^{14}C applications in karstic-systems. Suess-effect investigations by ^{14}C measurements of airborne and biological samples.

Courses taught:

Since 2000 in each semester I have held a laboratory exercise for students of the Department of Physics of the University of Debrecen. Since 2002 once in an academic year I have given an invited lecture in the course "Research of Quaternary" for students of the Department of Environmental Geography of the Eötvös Lóránt University in Budapest, Hungary. The title of this lecture is: "Principles and application of ^{14}C dating and stable isotope measurements".

Summary of application for Fermi Award 2008

DR. MIHÁLY MOLNÁR PHD.
HERTELENDI EDE LABORATORY OF ENVIRONMENTAL STUDIES, MTA ATOMKI, DEBRECEN

During my more than one decade practice in the Laboratory of Environmental Studies the main fields of interest for me were isotope analytical investigations and developments for the safety of different nuclear facilities.

In the beginning of my work I mainly focused on radiocarbon investigations in different mediums inside and outside the NPPs. In a comprehensive study we investigated the radiocarbon content in primary water, stack air and waste streams of several different European NPPs as Paks, Bohunice and Krsko Nuclear Power Plants.

During periodic steam generator cleaning by EDTA-complex one of the most important parameters is the knowledge of hydrogen- and nitrogen gas content in the steam. In co-operation with the chemists and engineers of the Paks NPP a portable quadrupole mass spectrometer was set and successfully applied in the concerned process.

After an accident of the NPP in the year of 2003 we investigated the effect of nuclear fuel rods to the composition of the dissolved gas in the cooling water of the cooling ponds of Paks Nuclear Power Plant (Paks NPP). The gases dissolved in the coolant, especially the ones produced by fission or decay, are good indicators of the variation in state parameters of the system in this situation as well as in the case of working reactors. For these aims I developed special sampling and measuring methods. Our results helped to ascertain the possible ways and rates of gas generation processes caused by the presence of nuclear fuel rods in the cooling water.

To understand environmental impact of Paks NPP I assisted in development and operation of different environmental monitoring networks around it. The activity of radiocarbon (^{14}C) in $^{14}CO_2$ and $^{14}C_nH_m$ chemical forms is measured in the vicinity of the NPP by sampling environmental air. Comparing our $^{14}CO_2$ measurements with data sets from Jungfraujoch and Schauinsland as well as from Košetice (Czech Republic) we demonstrated that the NPP has a definite but only a minor influence to the ^{14}C content of the atmosphere. We also developed and installed automatic groundwater sampling units into 20 observation wells in the vicinity of the reactor blocks at the end of 2000. The automatic sampling units are suitable for regular sampling of the groundwater for radionuclides, which are important in environmental safety point of view and inform us the physical state of the facility by monitoring the release of fission and corrosion products.

I carried out measurements in drum waste packages generated and temporarily stored in the site of Paks Nuclear Power Plant (NPP) and in two near surface low and intermediate level radioactive waste (L/ILW) vaults located in the Centralized Radioactive Waste Treatment and Disposal Facility (CRWTDF). I developed reliable gas-sampling devices and sample pre-treatment methods. I carried out successfully repeated sampling and measurements of twenty-five L/ILW drums of Paks NPP for wide range storage period. I also carried out post closure headspace gas sampling and analysis from two near surface L/ILW vaults of the CRWTDF. I developed a sample pre-treatment method and device for isotope-analytical measurements of headspace gas samples. Using my experimental data of composition variations of headspace gases of L/ILW drums for longer than two-year storage period, for the first time I made calculations to determine gas generation rates in the case of applied packaging method of Paks NPP. I measured the ^{3}H and ^{14}C activity concentrations in hydrogen, water vapor, methane and carbon-dioxide from the headspace gas of L/ILW packages.

The 2011 awardee: Balázs G. Madas

Curriculum Vitae of Balázs G. Madas, the 2011 awardee

I'm Balázs G. Madas, the 2011 awardee. My first experience in nuclear physics was related to the National Szilárd Leó Nuclear Physics Competition in 2002, where I got the 1st prize. During the preparation for the competition, I faced some open questions in physics, which confirmed my choice of undergraduate studies.

I graduated at the Institute of Nuclear Techniques, Budapest University of Technology and Economics as major in Engineering-Physics in 2007. Since that time, I have been working in the AEKI. In 2006, I began to study biomedical engineering in the same university and graduated in 2009. Both of my theses were prepared in the Atomic Energy Research Institute (AEKI) about the microdosimetry and biological effects of inhaled radon progeny. In 2009, I began my PhD studies at the Physics Graduate School of Eötvös University. My dissertation is being prepared under the supervision of Imre Balásházy in the AEKI again. I intend to finish my dissertation in winter 2012.

My main research interest is how radiation effects on cells manifest themselves at the tissue level. Because of the experience of our research group, we focus on the effects of inhaled radon progeny. However, I strive not to lose sight of the more general questions of radiation protection. Being familiar with related research fields is also important for me because of the interdisciplinary character of my interests. For this reason, I am member of several scientific associations, such as the Hungarian Nuclear Society, the Hungarian Biophysical Society, the Radiation Research Society, the Roland Eötvös Physical Society, and the European Respiratory Society. I am author or co-author of six international and two Hungarian journal papers. I participated in several international and national conferences.

I like playing board games with my wife, other games with my sons, and football with my friends.

The biological effects of ionizing radiation modeled at the tissue level: Mutation induction due to inhaled radon-progeny

BALÁZS G. MADAS
HUNGARIAN ACADEMY OF SCIENCES KFKI ATOMIC ENERGY RESEARCH INSTITUTE

One basic question of radiological protection, what the health consequences of the interaction between the human organism and ionizing radiation are. This question, however, is important regarding not only the radiological protection, because in long term the opinion of the society about applications of ionizing radiation is determined by that, in which depth we understand its health effects. For this reason, this question of radiological protection is very significant regarding the use of atomic energy, as well.

The biological effects of ionizing radiation can be studied at different levels of biological organizations with different limitations. Radiological protection is based on the effects on the population, which is the field of the epidemiology. With the decrease of doses, however, the uncertainties of the results extremely increase, until to a range, where epidemiology cannot predict the health effects. At the organism level (because of the ethical limitations of human experiments), animal experiments are possible. In this case, the main question is, how one can interpret the results regarding the effects on humans. Stepping forward, one arrives to level of tissues and cells, where the experiments are even more controlled, but one is even farther from the estimation of health effects.

The distance between experiments at cellular level and health effects can be well demonstrated by the case, when one is wondering, to which extent a given radiation burden increases the frequency of a given disease (e.g. cancer) in the population, and one measures the number of DNA damages and the differences in protein levels, which are probably related to cancer, but nobody knows how. For this reason, an important question of the investigations of radiation protection and radiation biology, what the relationships between the measurable radiation responses at the different levels of biological organization are. One subquestion of this question is, how the cellular effects of ionizing radiation manifest at the tissue level.

Obviously, nor this subquestion can be studied in general, because the effects at the cellular and tissue level and the relation between them depend on the radiation source and the tissue. Since the main part of radiation burden of the general population originates from inhaled radon progeny and 20 % of lung cancer cases is supposed to be related to radon daughters, the understanding of the effects of α-particles emitted by radon progeny on the epithelium of the central airways is of crucial importance regarding radiation protection and general health. For this reason, I started to investigate the biological effects of ionizing radiation at the tissue level, with particular attention to radon progeny. Among these effects, firstly, I studied, to which extent the mutagen effect of α-particles on the bronchial epithelium can be explained by DNA damages and to which extent by the increased cell division rate (increasing the spontaneous mutation rate) due to the increased cell death rate.

For this purpose, I have developed a mathematical model of the bronchial epithelium to study the biological effects of α-particles emitted by inhaled radon progeny. Some of the parameter values characterizing the mathematical model are very close to measured data, while other values are not so precise but still meet the requirements of the present investigation. According to our knowledge, this mathematical model of the bronchial epithelium is the first in the literature that is applicable for the simultaneous quantification of radiation exposure of cells and nuclei in cellular dosimetry calculations. I have computed α-particle hits of cell nuclei and cell doses of six different cell types as a function of radiation exposure (i.e., the number of decays per unit surface) at the most heavily affected parts of deposition hot spots in the bronchial airways.

I quantified the biological consequences of chronic radiation exposures with locally high dose rates by the adaptation and modification of a mutagenesis model. The results showed that modeling at the tissue level can enhance our knowledge about the biological effects of ionizing radiation, but at the same time pointed out the necessity of investigations at even higher levels of biological organization. Mutation induction at the tissue level has a completely different dose rate dependence than various cellular dosimetric quantities and individual cells' responses. On the basis of the shape of mutation induction curves, three different dose rate ranges can be distinguished.

I have found that acceleration of cell turnover due to cell inactivation is not only a significant contributor to, but a basic determinant of mutation induction in surviving progenitor cells in case of protracted exposures to densely ionizing radiation. This kind of bystander effect is important even at moderate or high doses where classical bystander effects are negligible compared to direct effects. By investigating the role of cell cycle shortening, I drew attention to the significance of the radiation burden of nonprogenitor cells in mutagenesis and pointed out that in vitro experiments on cell cultures can considerably underestimate the mutation induction rate per unit exposure rate in case of multicellular organisms chronically exposed to densely ionizing radiation.

In addition, I found a threshold of daily tissue dose for chronic exposures to α-particles, at which the tissue regeneration capacity of progenitor cells is exhausted (i.e., they cannot divide frequently enough to replace inactivated cells). To enhance the local tissue regeneration capacity, it seems plausible that the response of the tissue to the protracted exposure to high dose rate radiation (experienced by the bronchial cells in the particle deposition hot spots) is progenitor cell hyperplasia. The exhaustion of local tissue regeneration capacity and local hyperplasia beyond a threshold dose rate are suggested to be a possible reason for the inverse dose-rate effect (which disappears at low-dose rates or low cumulative doses) observed in the epidemiology of lung cancer among uranium miners. Lung cancer formation among uranium miners exposed to high radon progeny concentrations (more than 2–3 WL) is suggested to be driven by completely different mechanisms than other types of carcinogenesis induced by radiation.

Although all model parameters were obtained from experiments, some of the output values are in very good agreement with the results of other in vitro experiments without any parameter tuning. In other cases where existing experimental results are not appropriate to verify model predictions, new experiments were proposed.

The significance of the results regarding radiation protection can be summarized as the followings:

- I demonstrated that the effects of radiation on the organism cannot be predicted based on cell-level investigations, which is obvious, although not well-known.
- I pointed out, that even the radiation burden of nonprogenitor cells increases the mutation number (and *presumably* cancer risk too), which is neglected by many of the dosimetry models.
- I pointed out that lung cancer formation related to radon progeny can be driven by completely different mechanisms than other types of radiation carcinogenesis, which means that the decrease in acceptable radon levels does not necessarily implicate the necessity of the decrease of other limits and constraints of radiation protection.

The 2012 awardee: Gergely Papp

Curriculum Vitae, Gergely Papp

Born: 1985.07.04, Budapest.

Education, technical experience

2011: Licentiate of Engineering degree, Chalmers University of Technology, Sweden

2009- collaborative PhD training, Budapest University of Technology and Economics and Chalmers University of Technology, Sweden

2004-2009: MSc degree in Engineering-physics, BME, Budapest, Hungary.

2009: Extended radiation protection exam

2007-2009: student research contract (BME-NTI)

2006-2009: Attended 6 international summer universities & trainings

Foreign languages: English (professional), German (conversational), Swedish (beginner)

Teaching: Laboratory courses (2007-), exercise courses (2009-), guest lecturer (2009-), Supervisor of 2 Bsc- and 3 MSc students (2009-)

Computer knowledge: 7 years of professional experience in computer network and unix system administration, experienced in different HPC hardware and software techniques. Advanced knowledge of IDL, Matlab, Fortran, C, Maple (etc); LaTeX and Adobe DTP.

Offices: Secretary of the Fusion Section of the Hungarian Nuclear Society (2011-)
Competition Committee, Szilárd Leó Nuclear Physics Competition (2007-)

Honors and awards: „Pro Progressio“ PhD prize (2012), Pro Scientia Golden Medal Prize (2009), 1st prize at the National Scientific Student Conference (2009), 21 other awards and scolarships.

Publications: 8 journal articles, 19 papers in international proceedings, 14 oral presentations at international conferences/workshops/seminars.

Application for the Fermi Young Researcher's Award

GERGELY PAPP
BUDAPEST UNIVERSITY OF TECHNOLOGY AND ECONOMICS &
CHALMERS UNIVERSITY OF TECHNOLOGY

I have started my research work in 2004, as an undergraduate student at the Institute of Nuclear Techniques, Budapest University of Technology and Economics (BME-NTI). From the very beginning my research interest was mainly connected to controlled magnetic fusion. To our present knowledge, fusion possesses most of the aspects of an almost ideal energy source. The realisation of this appealing concept, however, poses an enormous scientific and technological challenge, partly because the behaviour of fusion plasma is not completely explored.

Most of my research work is connected to the tokamak type of fusion reactors. In these reactors the 100 million degree hot material is in the plasma state of matter, which is isolated from the surroundings in a torus shaped chamber with strong (up to 8 T) magnetic fields. The presence of the magnetic field poses a variety of challenges. As low as 0.1% distortion of the carefully constructed stable plasma equilibrium field can lead to a drastic increase in transport and degradation- or loss of plasma confinement. My interest lies within understanding the exact mechanism behind magnetic perturbations in order to explore the corresponding threats and possible applications. My research work constitutes of somewhat different but closely connected parts. It involves both analytical/theoretical, experimental and numerical simulation subtasks that have to be carried out in a symbiosis.

During my university years I was mostly working with transient magnetohydrodynamic (MHD) modes of fusion plasmas and their effect on plasma transport. I have participated in the development of various data analysis methods and tools based on time-frequency analysis in order to detect MHD waves and explore their interaction and spatial structure. The experimental work was accompanied by theoretical calculations and numerical work. This project was awarded with several OTDK and TDK prizes (National and Local Scientific Student Conference) as well as conference and journal papers. For the research work carried out during my university years I was selected for the 2008 Lindau Nobel Laureates Meeting and in 2009 I was awarded the „Pro Scientia Golden Medal Prize" in 2009. As of today I hold a total of 24 different awards, scholarships and grants.

After defending my MSc in 2009, I enrolled in the joint PhD programme of BME and Chalmers University (Gothenburg, Sweden) in the PhD schools of Physics (BME), and Nuclear Engineering (Chalmers). My PhD topic is the investigation of suprathermal particle populations and related instabilities in fusion plasmas. High-energy particles are of prime importance for the heating of the plasma, and are necessary for a self-sustaining reaction. Understanding the behaviour of suprathermal particles is a key element of the realisation of fusion energy production. On the other hand, the avalanche generation of fast particles or the excitation of different energetic plasma instabilities threatens the feasibility of energy production, or threatens even the reactor itself. For these reasons it is extremely important to understand fast particle dynamics and develop reliable control mechanisms.

I have spent my university internship at the Max-Planck-Institut für Plasmaphysik (IPP) in Munich. I started to work on the transient transport phenomenon of the core plasma known as the „sawtooth crash”. During the sawtooth instability, high energy core ions coming from plasma heating or fusion reactions can destabilise plasma waves, which in turn expel the dense and hot plasma core to outer regions, leading to the degradation or complete stop of fusion reactions. The process continues in a quasiperiodic way leading to the sawtooth-like jumps of core electron temperature (hence the name). The phenomenon has been known for almost 40 years, but a complete and consistent theoretical explanation was lacking. During my experimental work on the ASDEX-Upgrade tokamak in Munich I have explored a secondary wave that appears as a sideband of the main instability. This secondary wave has a lower frequency and gains energy just before the sawtooth crash. This investigation wouldn’t have been possible without the sensitive Fourier- and Wavelet-based techniques that were developed by the fusion group of BME-NTI. With detailed data analysis I have determined the spatial-, time-, frequency- and energy evolution of the secondary wave. Experimental proof was found for the nonlinear interaction of the wave with the main harmonic. My modelling based on nonlinear dynamics and chaos theory showed that the interaction of these two waves leads to such a change in core magnetic topology, which can trigger the sawtooth crash. These results have contributed to the understanding of sawtooth crashes, and therefore a better and reliable control of the plasma core and hence the fusion reactions.

The research topic that I pursue as my main interest is strongly connected to sawtooth modelling in terms of theoretical description. In plasmas the friction force is a result of continuous, small angle scattering Coulomb-collisions. This has the unique feature that in plasmas the friction force is not a monotonic function of energy; it drops after reaching a maxima. If a sufficiently strong electric field is present in the plasma, that will lead to the generation of highly relativistic particles, which are called runaway electrons. Under non-standard operational conditions like plasma terminating disruptions such a high electric field can form and generate a runaway electron beam. These 10-100 MeV particles collide with background particles leading to an avalanche multiplication of runaways, that can build to up to 10 MA in current (ITER). If the beam hits the vessel the localised heat load can reach up to 100-1000 MW/m2, causing serious damage to the reactor wall. The characteristic timescale of the process is on the order of a few 10 ms, therefore a reliable control mechanism is an extreme technological challenge.

The next step in fusion research is the ITER tokamak that will demonstrate the self-sustaining nature of fusion energy production as well as positive energy balance and the feasibility of the concept. The presence of runaway avalanche beams cannot be tolerated in ITER, and therefore it is necessary to develop various security systems that can prevent or mitigate the runaway beam. During the largest portion of my research time I am involved in the development of the so-called resonant magnetic perturbation (RMP) runaway suppression system of ITER. As I have mentioned before, as small as 0.1% distortion of the magnetic structure can lead to a huge increase in plasma transport. The general description and modelling of the process is based on nonlinear dynamics and chaos theory, and has the same principles that were used to understand sawtooth physics. In this case we use the effect to our advantage. An optimized external coil system is capable of reducing plasma confinement in a controlled way, that leads to the removal of runaway electrons before avalanche multiplication could kick in, and therefore the wall heat load can be decreased by several orders of magnitude. A properly chosen configuration can position the wall heat loads and avoid sensitive parts of the vessel such as heating antennae. Due to the complexity of the problem 3D numerical analysis had to be carried out. The calculations take into account the relativistic drift of the particles, Coulomb collisions and various radiation processes. In the simulations arbitrary 3D geometries can be used, which is a key factor for optimization.

The program package was validated on RMP systems installed in smaller scale tokamaks. By using the described apparatus I was able to determine the effectiveness of the technologically achievable strongest RMP system for ITER. The perturbation current pattern design that I have developed and optimized is capable of removing runaway electrons from the outer 50% of the confinement volume on the timescale of 1-10 microseconds, that can lead to orders of magnitude decrease in wall heat loads. I have also determined the spatial localisation of the wall loads as a result of RMP, which can be controlled by properly positioning the perturbation pattern. My design offers a balance between fast runaway removal and possible heat load localisations. As a by-product of this work I was able to extend the general description of particle transport theory in perturbed magnetic topologies. As a result of my research achievements I have been invited to the prominent Massachusetts Institute of Technology (MIT) to give seminar lectures.

Since the RMPs are only partially effective, other mitigation methods based on massive gas- or impurity injection are also being developed worldwide. In 2012 I started to work in modelling the effect of various material injections on runaway electron dynamics. The project is carried out in a close collaboration between numerical simulations and experimental work, several journal papers are in preparation. My international collaborations involve some of the most prominent international fusion laboratories such as the ITER Organization, CCFE/JET (UK), IPP (Germany), FZ-Jülich (Germany), General Atomics (USA), MIT (USA), etc.

During runaway electron generation an exotic process is also taking place. The presence of runaway electrons lead to the generation of high-energy long living positrons: tokamak disruptions are among the strongest man-made positron sources. On top of the intrinsic interest of the phenomenon, positrons also carry valuable information about plasma parameters that are otherwise hard to diagnose during the disruption. With analytical calculations based on kinetic theory, we were able to determine the distribution function of runaway positrons, which in turn was used to determine the synchrotron radiation of the positron population. Since the spectrum shape is sensitive to various plasma parameters, measuring the radiation with visible/IR cameras can provide a lot of information about the background plasma. Our results were published in Physical Review Letters.

My complete publication list and a 1-page CV are attached to this application. In 2012 I was awarded with the “Pro Progressio” PhD prize. As of today I have 8 journal papers and 19 conference papers, most of them as first author. I have spent more than two years in various foreign institutes (Sweden, Germany, USA, UK, etc.). In June of 2011, one and a half years into the PhD program I have acquired the “Licentiate of Engineering” scientific title in Sweden. Links to the thesis and diploma can be found in my CV/publications.

I am involved in various teaching activities in the field of nuclear science since 2007. I have also supervised 2 BSc and 3 MSc students. I am involved in the Committee of the Szilárd Leó National Nuclear Physics Competition since 2007. I participate in various popular science activities such as public- and school lectures, and I am the secretary of the Fusion Section of the Hungarian Nuclear Society.

Current position of the Fermi awardees

Ákos Horváth (2002) – *director*

MTA Centre for Energy Research, Atomic Energy Institute

Anikó Kerkápoly (2003) – *assistant professor*

Budapest University of Technology and Economics, Institute of Nuclear Techniques

Tamás Pázmándi (2004) – *head of laboratory*

MTA Centre for Energy Research, Radiation Protection Laboratory

Rita Dóczi (2005) – *associate professor*

Budapest University of Technology and Economics, Institute of Nuclear Techniques

Gergő Pokol (2007) – *associate professor*

Budapest University of Technology and Economics, Institute of Nuclear Techniques

Árpád Farkas (2008) – *researcher*

MTA Centre for Energy Research, Environmental Physics Laboratory

Mihály Molnár (2009) – *assistant head of laboratory*

Institute of Nuclear Research of the Hungarian Academy of Sciences,
Hertelendi Laboratory of Environmental Studies

Balázs G. Madas (2011) – *junior researcher*

MTA Centre for Energy Research, Environmental Physics Laboratory

Gergely Papp (2012) – *PhD student*

Budapest University of Technology and Economics & Chalmers University of Technology