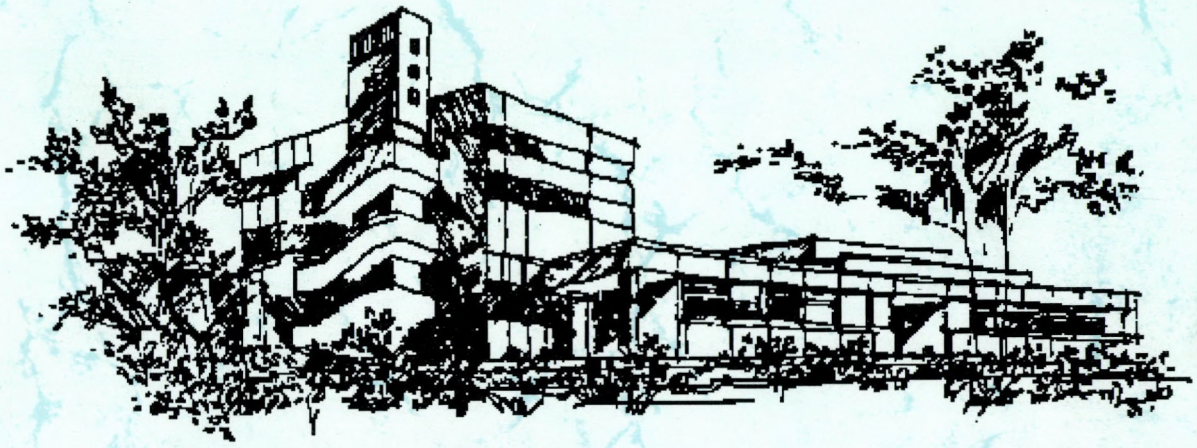
ATOMKI

ANNUAL REPORT 2003



INSTITUTE OF NUCLEAR RESEARCH
OF THE HUNGARIAN ACADEMY OF SCIENCES
DEBRECEN, HUNGARY

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Preface

In 2003 there appeared lots of interesting results and hopes for the future of Atomki.

We managed to improve the instrumentation of our laboratories. The radiofrequency unit of the cyclotron has been replaced successfully, and the new unit now seems to promise many years of stable operation ahead. The *Tandetron*-based accelerator mass spectrometer (AMS), which was received from Oxford at the end of 2002, is being installed. The work is going on slowly, but that is a blessing in disguise since the delay is caused by other fruitful activities. The installation work is being done by the personnel of the electrostatic accelerators, and they are very busy with operating on the old Van de Graaff accelerator. The demand for the Van de Graaff has enormously increased mainly because of two national and two European projects that are going on there. We still hope that the installation will be completed by the end of 2004, but that will be the subject of another Annual Report. Atomki and the Department of Solid State Physics of the University of Debrecen have jointly won a secondary-ion mass spectrometer (SIMS), which can also be operated so as to produce secondary neutral atoms (SNMS mode of operation). It will be installed in Atomki and will be a very useful tool for surface physics research.

Last year was a year of books. At the beginning of the year the large book *Structure and Reactions of Light Exotic Nuclei* by Y. Suzuki, myself, K. Yabana and K. Varga appeared at Taylor & Francis, London. At the very end of the year the huge five-volume *Handbook of Nuclear Chemistry*, ed. by A. Vértes, S. Nagy and Z. Klencsár (Kluwer Academic, Dordrecht etc.) appeared, with a number of contributions by Atomki members (by T. Fényes, by D. Horváth, by J. Csikai and R. Dóczi, by E. Koltay, A. Z. Kiss and others and by S. Biri, E. Koltay and A. Valek), and with my participation as editor of Volume I. Towards the end of the year, we managed to publish the highly successful popular nuclear physics book by Ray Mackintosh, Jim Al-Khalili, Björn Jonson and Teresa Peña: *Nucleus. A Trip into the Heart of Matter.* It appeared in Hungarian at Akadémiai Kiadó, Budapest. The cause of this book was pushed ahead by some Atomki members, acquiring the support of the Ministry of Education, translating (Z. Gácsi and A. Simon) and revising the text, in which even my language-minded son was involved. The book was presented to the public by Ray Mackintosh in a large book-shop of Budapest, and it induced acclaim in the press.

To herald the appearance of this book, the subject of the Physics Days, the local 'public feast' of physics, was *nuclear physics.* All but one of the public lectures were on nuclei ('The Look of Nuclei' by myself, 'The Oldest Nuclei' by I. Lovas, Debrecen University, 'Stars and Nuclei' by E. Somorjai, Atomki, and 'Molten Nuclei' by P. Lévai, Budapest). The single extra subject was a talk to teachers: 'How to Do Demonstration Experiments?' by K. Härtlein (Budapest). Another success in popularizing physics is the Hungarian version of the exhibition entitled *Radioactivity: a Facet of Nature*, which we adopted a year earlier, but was now shown at Eötvös University, Budapest, and at a local school at the town of Baja.

We had two scientific meetings in Atomki: a National Meeting of Speleologists, 7–9 November, organized by Z. Dezső and other members of the Department of Environmental Physics, and an Austrian-Hungarian Workshop on Charged-Particle Transport through Nanostructures and Solids, 14–16 November, organized by K. Tőkési. (Note the fine distinction between Austro-Hungarian and Austrian-Hungarian!) At the scientific sessions adjoining the May Assembly of the Hungarian Academy of Sciences we had two talks: *Recent Results of Perturbative Quantum Field Theory* by Z. Trócsányi and *'Debrecenbe kéne menni'. Participation in CERN CMS.* ('Debrecenbe kéne menni' is the title of a folksong: 'One should go to Debrecen'.) There was another session of the Academy of Sciences with our participation: in November we commemorated the late Honorary Member of the Academy, Edward Teller, who had died in September. On this occasion talks were given by A. Krasznahorkay and J. Csikai, on the *Investigation of Collective Nuclear Excitations Following Teller* and on *Teller's Home-coming to Hungary*, respectively.

To give the local 'Honours List', I should first mention that Borbála Gyarmati, Professor Emeritus Instituti, was decorated with the 'Eötvös Wreath', which is the highest award of the Academy to be given to non-members. *Prof. Zoltán Trócsányi* won the Award of the Academy for his results in

the application of perturbative quantum chromodynamics. (I announced this, wrongly, in the Annual Report on 2002. It seems I can either read the future or I wrote the preface to the previous Annual Report very late.) The Szalay Prize of the Institute for basic research was awarded to Dr. Gábor Kalinka. He is a great asset of this Institute: he knows everything about scintillators and semiconductor detectors. He is able to make excellent detectors because he really *understands* how they work. In this way, he has contributed not only to applied solid-state physics but also to basic atomic and nuclear physics, and his role is also essential for our international projects on nuclear physics. Finally, Dr. Attila Csík was awarded the Ferenczi Prize for his studies of diffusion in multilayers. This prize is dedicated to young researchers of semiconductors in Hungary. It should also be mentioned that Dr. Géza Lévai has been made DSc based on his work on the symmetries of basic quantum mechanical potential problems.

After years of preparations, in 2003 Hungary became a member of the Nuclear Physics European Collaboration Committee (NuPECC). The country is represented by our Atomki colleague, Dr. A. Krasznahorkay.

Last autumn the performance of the institutes of the Academy of Sciences was reviewed. The interim conclusion on Atomki is very positive. At present, however, we are more interested in current results. I have singled out three things rather arbitrarily.

Prof. D. Horváth, who is affiliated primarily to the Research Institute for Particle and Nuclear Physics, Budapest, has been working on antiprotonic atoms with his Debrecen student, B. Juhász for a few years. They take part in the ASACUSA project at CERN, which is mainly a Japanese endeavour, with a significant contribution of the two Hungarians. The major feat of ASACUSA has been a precise determination of the antiproton mass and charge, which are used in the most precise validation of CPT symmetry (i.e., invariance of the laws of nature under the joint effect of charge conjugation, space reflection and time reversal transformations). Juhász's own contribution is most significant in exploring the effects, on the lifetime of antiprotonic helium atoms, of hydrogen and deuterium molecules mixed into the helium target gas, in which the antiprotonic helium is produced.

There is a small team of Atomki physicists (S. Ricz, Á. Kövér and others) regularly visiting the Max-II synchrotron (Lund) and making photo-ionization measurements in cooperation with colleagues from the University of Oulu. Their observations have caused a bit of a surprise to atomic physicists. The conventional idea assumes photo-ionization to be a primarily dipole process, but their high-resolution measurements of the angular distribution of electrons knocked out by <1 keV linearly polarized photons shows that that is far from being the case. Quadrupole and possibly also higher-order contributions are significant, and photo-ionization produces a hierarchy of broad structures of particle-hole excitations, similar in essence to the giant multipole resonances of nuclei.

A Debrecen team (M. Hunyadi, A. Krasznahorkay and others) are taking part in giant resonance studies at KVI, Groningen. Their most significant recent result has been an identification of an isoscalar dipole resonance with low background. It was excited by (α, α') scattering, and the background was greatly reduced by the observation of the nucleonic decay of the resonance. While isovector dipole states are most common, isoscalar dipole states are most exotic. An isoscalar dipole oscillation involves an oscillation of the centre of mass of the nucleus, which is only possible as a higher-harmonic compressional vibration of the matter of the nucleus. Thus the position of an isoscalar dipole mode depends on the incompressibility of nuclear matter, so that the latter can be determined from the former.

For the sake of completeness, one should mention that, from 1st March, 2003, the Section of Electrostatic Accelerators is headed by Dr. Zsolt Fülöp. Moreover, on 1st August, 2003, the Section of Nuclear Spectroscopy assumed a new name, the Section of Experimental Nuclear Physics.

The financial and personnel conditions in 2003 are given in the pie charts to follow this Preface.

This Report, prepared in LaTeX, is available on the web at www.atomki.hu in PDF format.

Debrecen, 6 April 2004

Rezső G. Lovas
Director

Organizational structure of ATOMKI

Director:	R.G. Lovas, D.Sc.
Deputy directors:	Á.Z. Kiss, D.Sc.
	S. Mészáros, C.Sc.
Finance director:	Dr. M. Pálinkás

- Secretariat (Scientific Secretary: Á. Kovách, C.Sc.)
- Library (Librarian: Mrs. M. Nagy)
- Accounting (Head: Mrs. J. Sass)
- Basic Services and Maintenance (Head: Mr. I. Katona)
- Mechanical Workshop (Head: Mr. I. Gál)

Scientific Sections

Division of Nuclear Physics (Head: J. Cseh, D.Sc.)

- Section of Experimental Nuclear Physics (Head: A. Krasznahorkay, D.Sc.)
- Section of Electrostatic Accelerators (Head: Zs. Fülöp. Ph.D.)
  - Nuclear Astrophysics Group
  - Ion Beam Analysis Group
- Section of Theoretical Physics (Head: T. Vertse, D.Sc.)

Division of Atomic Physics (Head: Á. Kövér, D.Sc.)

- Section of Atomic Collisions (Head: L. Sarkadi, D.Sc.)
- Section of Electronspectroscopy (Head: D. Varga, C.Sc.)

- Section of Environmental and Earth Sciences (Head: Á.Z. Kiss, D.Sc.)
  - Laboratory of Environmental Studies
  - Radon Group
  - K-Ar Laboratory
  - Radiation- and Environmental Protection Group
  - QMS Laboratory
- DE TTK - ATOMKI Department of Environmental Physics (Head: Á.Z. Kiss, D.Sc.)
- Cyclotron Section (Head: F. Tárkányi, C.Sc.)
- Section of Electronics (Head: J. Gál, C.Sc.)

Data on ATOMKI

At present the Institute employs 198 persons. The affiliation of personnel to units of organization and the composition of personnel are given below.

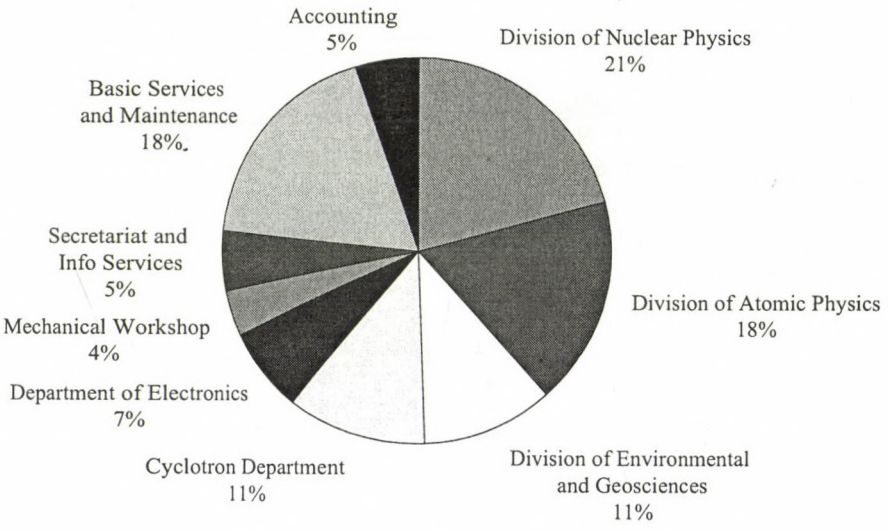

Figure 1. Affiliation of personnel to units of organization

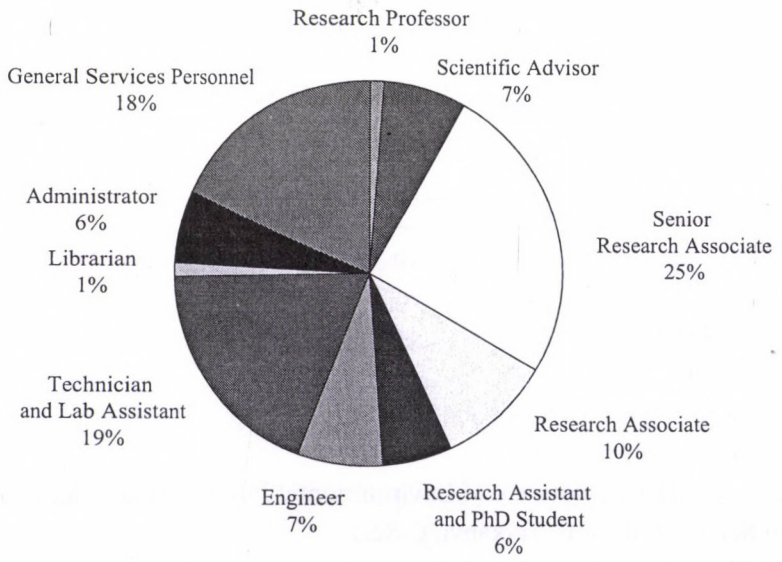

Figure 2. Composition of personnel

Finance

The total budget of the Institute for the year 2003 was 1160 million Hungarian Forints. The composition of the budget and the share of personnel expenditure within the budget are shown below.

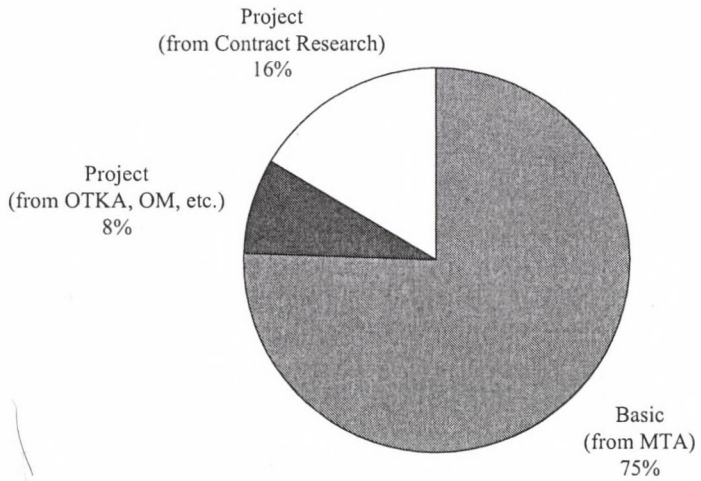

Figure 3. Composition of the budget of the Institute

MTA: Hungarian Academy of Sciences
OTKA: National Fund for Scientific Research
OM: Ministry of Education

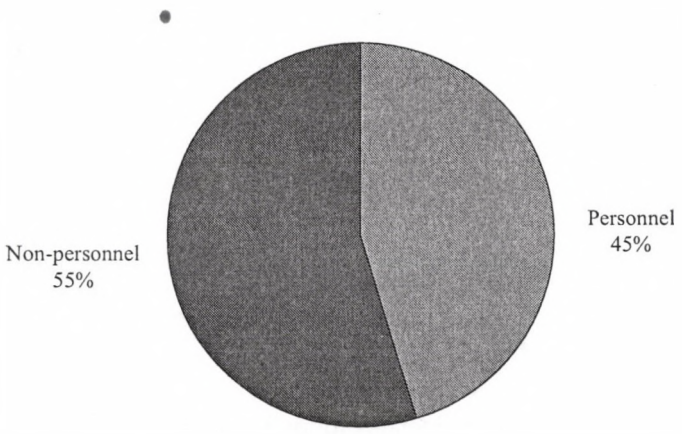

Figure 4. Breakdown of expenditure into personnel and non-personnel expenditures

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1.1 $\mathcal{PT}$ symmetry beyond the shape-invariant potential class

G. Lévai, P. Roy [a], A. Sinha [b]

The concept of $\mathcal{PT}$ symmetry, i.e. the invariance under simultaneous space ($\mathcal{P}$) and time ($\mathcal{T}$) reflection appeared in quantum mechanics just a few years ago [1]. Potentials admitting this symmetry are complex, but they have the unusual property that their energy eigenvalues can be *real*. It was also found that tuning some potential parameters the real energy eigenvalues can merge pairwise and reemerge as complex conjugate pairs, and this phenomenon can be interpreted as the spontaneous breakdown of $\mathcal{PT}$ symmetry.

Although the first $\mathcal{PT}$-symmetric potentials were found in numerical studies [1], the $\mathcal{PT}$-symmetric versions of the most well-known real potentials were also constructed soon. It was found that except for the Morse and Coulomb potentials the members of the shape-invariant potential class can be generated in a straightforward way by applying an imaginary coordinate shift $x \to x + \mathrm{i}\epsilon$ and by setting some potential parameters to real or imaginary values [2]. The $\mathcal{PT}$-symmetric shape-invariant potentials defined this way exhibit a number of unusual features: *i)* They have *two* sets of normalizable solutions, and their states having the same principal quantum number n can be distinguished by the quasi-parity quantum number q. The extra states ultimately appear due to the less strict boundary conditions, as the imaginary coordinate shift cancels the singularities at $x = 0$, for example. *ii)* The spontaneous breakdown of $\mathcal{PT}$ symmetry sets in at the same potential parameter for all the levels. *iii)* Due to the two sets of normalizable solutions, these potentials have *two* supersymmetric partners (distinguished by q), and these are $\mathcal{PT}$-symmetric as long as the original potential also has this property. However, when the $\mathcal{PT}$-symmetry of the original potential is spontaneously broken, its supersymmetric partners have manifestly broken $\mathcal{PT}$-symmetry.

It is natural to raise the question whether the features outlined above characterize exclusively shape-invariant potentials, or they are shared by further potentials beyond this class. For this we analyzed the $\mathcal{PT}$-symmetric version of the generalized Ginocchio potential [3]

$$V(r) = \frac{\gamma^4[\lambda(\lambda-1)\coth^2 u + \gamma^2 - 1 - s(s+1)]}{\gamma^2 + \sinh^2 u} - \frac{3\gamma^4(\gamma^2-1)(3\gamma^2-1)}{4(\gamma^2+\sinh^2 u)^2} + \frac{5\gamma^6(\gamma^2-1)^2}{4(\gamma^2+\sinh^2 u)^3}\,, \tag{1}$$

which belongs to the more general Natanzon potential class, and contains the (shape-invariant) generalized Pöschl–Teller potential as a special case (with $\gamma = 1$). This potential depends on the $u(r)$ function, which is defined implicitly by the

$$\frac{\mathrm{d}u}{\mathrm{d}r} = \frac{\gamma^2 \cosh u}{(\gamma^2 + \sinh^2 u)^{\frac{1}{2}}} \tag{2}$$

differential equation. In spite of its implict definition, the $r \to x + \mathrm{i}\epsilon$ imaginary coordinate shift can be applied to $u(r)$ too, and one finds that the $u(x)$ function modified in this sense is $\mathcal{PT}$-odd, i.e. $\mathcal{PT}u(x) = -u(x)$, and this helps to identify the transformation properties of the potential and its solutions. Our study showed that the $\mathcal{PT}$-symmetric generalized Ginocchio potential shares all the features of $\mathcal{PT}$-symmetric shape-invariant potentials generated by an imaginary coordinate shift. These features seem to be valid in an even broader range, since they hold for a particular supersymmetric partner of the harmonic oscillator, found outside the the Natanzon class [4].

a) Indian Statistical Institute, Kolkata, India

b) Calcutta University, Kolkata, India

[1] C. M. Bender, S. Boettcher, Phys. Rev. Lett. **24** (1998) 5243.

[2] G. Lévai, M. Znojil, J. Phys. A **33** (2000) 7165; Mod. Phys. Lett. A **16** (2001) 1973.

[3] G. Lévai, P. Roy, A. Sinha, J. Phys. A **36** (2003) 7611.

[4] A. Sinha, G. Lévai, P. Roy, Phys. Lett. A, in press.

2.1 Electron screening in d(d,p)t for deuterated metals: a systematic study

Zs. Fülöp, Gy. Gyürky, E. Somorjai for the LUNA collaboration

We continued our systematic study [1] on the anomalous enhancement of electron screening potential (U_e) for the d(d,p)t reaction in deuterated metals.

The 100 kV accelerator of the Dynamitron-Tandem-Laboratorium at the Bochum University provided the deuteron beam with a 54 μA current on target. A liquid-nitrogen-cooled Cu tube extended to within 5 cm of the target. Four Si detectors were installed at an angle $\theta = 130°$ relative to the beam axis at a 5 cm distance from the target and covered with a Ni foil to stop the intense flux of elastically scattered particles. The target together with the chamber and the detector holders (including the Ni foils) formed a Faraday cup for beam integration. A negative voltage of 200 V was applied to the Cu tube for suppression of secondary electrons.

Each deuterated target was produced in the following way: a fresh material "M" (with a purity of better than 99%) was in situ cleaned by Kr sputtering at 35 keV removing about 200 monolayers. Then, the target was bombarded with 10 keV deuterons, whereby the proton yield of d(d,p)t was recorded as a function of implantation charge: the yield reached a saturation level usually after a charge of about 1 C, i.e. a stoichiometry M_xD has been produced near the surface of the target. The procedure was repeated at $E_d = 30$ keV. The deuteron distribution was investigated subsequently via Elastic-Recoil-Detection-Analysis (ERDA) and Rutherford-Back-Scattering-Analysis (RBS). For most of the materials the distribution was uniform within 10% from the surface down to a depth consistent with the range of the implanted deuterons.

The observed enhanced cross section is most likely due to electron effects of the environment of the target deuterons. In one experiment, we also used a deuterated Pt target and a ^{3}He ion beam in the reaction d(^{3}He,p)^{4}He to study the associated electron screening effect. The result is $U_e = 730 \pm 60$ eV showing that such high U_e values do not depend on the kind of ion species but are a feature of the deuterated metals.

The results in relation to the periodic table [2,3] indicate a common feature: where more than one element of a given group of the periodic table has been studied so far, the corresponding U_e values are either low ("gaseous") as for Ti, Zr, and Hf (group 4), Cu, Ag, and Au (group 11), and B and Al (group 13), or high such as for V, Nb, and Ta (group 5), Cr, Mo, and W (group 6), Mn and Re (group 7), Fe and Ru (group 8), Co, Rh, and Ir (group 9), Ni, Pd, and Pt (group 10), and Zn and Cd (group 12). Group 14 is an apparent exception to this feature: the metals Sn and Pb have a high U_e value, while the semiconductors C, Si, and Ge have a low U_e value indicating that high U_e values are a feature of metals.

The indication is supported by other insulators (B, BeO, Al_2O_3) as well as by deuterated metals M having an observed small stoichiometric x value (M_xD) of the order of one or smaller and thus representing also insulators (e.g. group 4 of the periodic table and the lanthanides). In summary, a large screening effect is observed in all metals except in the noble metals Cu, Ag, and Au.

[1] F. Raiola *et al.*, Phys.Lett. B547 (2002) 193.

[2] F. Raiola *et al.*, Nucl. Phys. A719 (2003) 61.

[3] C. Bonomo *et al.*, Nucl. Phys. A719 (2003) 37.

2.2 Absolute resonance strengths in the ^{6,7}Li$(\alpha,\gamma)^{10,11}$B reactions

Gy. Gyürky, Zs. Fülöp, E. Somorjai, G. Kiss and C. Rolfs[a)]

The ^{12}C$(\alpha,\gamma)^{16}$O reaction is one of the key reactions of nuclear astrophysics [1]. For this reason its cross section at the relevant low energies must be known with a precision of at least 10%. The European Recoil Separator for Nuclear Astrophysics (ERNA) project [2] is in progress in Bochum, Germany to determine this cross section with a novel experimental technique: a ^{12}C ion beam is guided into a windowless ^{4}He gas target and the ^{16}O recoils are counted in a ΔE-E telescope placed in the beam line at the end of the separator, which filters the intense ^{12}C projectiles from the ^{16}O recoils. One of the most important separator characteristics is its acceptance in angle and energy. One way of determining the acceptance experimentally is to use nuclear reactions with well known absolute cross sections, such as resonant α-capture reactions involving the ^{4}He gas target of ERNA. If a reaction with a chosen resonance energy has similar kinematics as ^{4}He(^{12}C,γ)^{16}O, the angular and energy spreads of the ^{16}O recoils can be simulated. This condition is fulfilled by the narrow and strong resonances at $E_{R,c.m.} = 706$ keV in ^{4}He(^{6}Li,γ)^{10}B and $E_{R,c.m.} = 518$ keV in ^{4}He(^{7}Li,γ)^{11}B. However, the strength $\omega\gamma$ of these resonances is not known with sufficient precision, *i.e.* better than 10%. Thus, in our present work we remeasured both strengths.

The experiments were carried out at the 5 MV Van de Graaff accelerator of the ATOMKI. The resonance strengths were measured using an α beam (5 - 10 μA) on LiF targets with natural isotopic abundance. The resonance strengths were derived from the yield of the most intense γ-radiations following the α-capture. The γ-ray yield was observed with a 40% High Purity Germanium detector. At γ-energies below 4 MeV (relevant to ^{6}Li$(\alpha,\gamma)^{10}$B), the absolute efficiency of the detector was measured using calibrated radioactive sources, while at higher energies (relevant to ^{7}Li$(\alpha,\gamma)^{11}$B) resonant reactions emitting cascade γ-rays were used to determine the efficiency.

For both studied resonances we scanned the resonance energy region in 1 keV steps in order to measure the resonance profile.

For the strength of the $E_{R,c.m.} = 706$ keV resonance in the ^{6}Li$(\alpha,\gamma)^{10}$B reaction we obtained $\omega\gamma = \mathbf{366 \pm 38\ meV}$ which is within the uncertainty range of the adopted value $\omega\gamma_{adopted} = 400 \pm 40$ meV [3]. Based on the weighted average of the results of all available measurements we propose a new standard value $\omega\gamma_{new} = 387 \pm 27$ meV which is consistent with all measurements.

The obtained walue for the strength of the $E_{R,c.m.} = 518$ keV resonance in the ^{7}Li$(\alpha,\gamma)^{11}$B reaction is $\omega\gamma = \mathbf{300 \pm 32\ meV}$ which is in excellent agreement with the adopted value $\omega\gamma_{adopted} = 310 \pm 47$ meV [4] based on a single experiment. Averaging these two values we propose as a new standard value $\omega\gamma_{new} = 304 \pm 26$ meV.

With the results from previous and present work the precision of the strength of the two resonances has become better than 10% allowing for the ERNA project (and other recoil separators) to perform a reliable acceptance measurement based on these resonant reactions.

a) Institut für Physik mit Ionenstrahlen, Ruhr-Universität Bochum, Bochum, Germany

[1] C. Rolfs and W.S. Rodney: Cauldrons in the Cosmos (University of Chicago Press, 1988)

[2] D. Rogalla *et al.*, Nucl. Instr. Meth. A 437 (1999) 266.

[3] F. Ajzenberg-Selove, Nucl. Phys. A 490, (1988) 1.

[4] F. Ajzenberg-Selove, Nucl. Phys. A 506, (1990) 1.

2.3 Astrophysical S-factor of $^{14}N(p,\gamma)^{15}O$

Zs. Fülöp, Gy. Gyürky, E. Somorjai for the LUNA collaboration

The capture reaction $^{14}N(p,\gamma)^{15}O$ is the slowest process in the hydrogen burning CNO cycle and thus of high astrophysical interest. This reaction plays a role in setting the energy production and neutrino spectrum of the sun as well as in the age determination of globular clusters. The minimum energy explored in overground laboratories is ~ 240 keV, well above the range of interest for the stellar CNO-burning (20-80 keV). Therefore, the reaction rate used in stellar model calculations is largely extrapolated, in a region, where the resonant structure of the ^{15}O compound nucleus is particularly complex.

The astrophysical S(E)-factor at zero energy has contributions from the transitions to the ground state in ^{15}O and to the subthreshold state at $E_{cm} = -504$ keV. According to Ref. [1] the ground state transition has an important contribution from the subtreshold state, while Ref. [2] having reanalyzed the experimental data of [1] found only a negligible contribution. In both cases the R-matrix formalism was used for the fitting procedure.

The LUNA collaboration significantly improved the low energy measurements of this reaction rate, using the 400 kV underground facility at Gran Sasso National Laboratory, where cosmic background is strongly suppressed by the mountain shielding and low intrinsic activity detectors are employed. The target consisted of a TiN layer (with a typical thickness of 80 keV) reactively sputtered on a 0.2 mm thick Ta backing. The target quality was checked frequently at the $E_R = 259$ keV resonance: no significant deterioration was observed after a bombarding time of several days. Also, the beam-induced background in different target backing materials were studied in details [3]. The explored energy window ranges from 390 keV down to 135 keV, significantly closer to the astrophysical relevant energy than any previous experiment. Our experiments also revealed the importance of the cascade corrections in the absolute γ-efficiency determination in close geometry for the transitions studied. The fit of the new data and the corrected data of [1] by means of R-matrix model is shown in Fig.1.

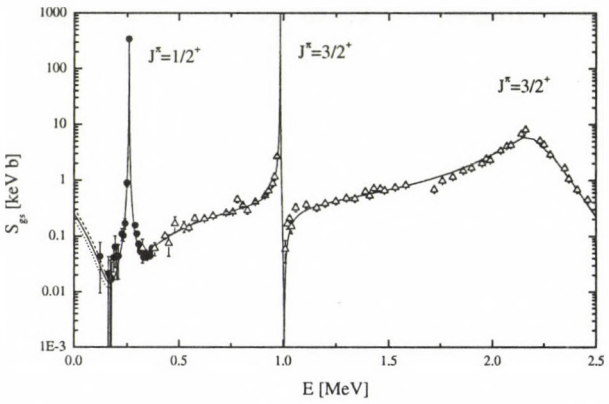

Fig. 1. Astrophysical S(E)-factor curve for the ground state transition in $^{14}N(p,\gamma)^{15}O$. Filled-in data points are the results from LUNA, while the open data points are from previous work [1] corrected for summing effects. The solid, dashed and dotted lines correspond to the R-matrix fits for radii a = 5.5 fm, a = 6 fm and a = 5 fm, respectively.

Our result [4] supports that the contribution of the subthreshold state to the total S(E)-factor is negligible above 100 keV, and the deduced value is $S_{tot}(0) = 1.7 \pm 0.1$ (stat) ± 0.2 (syst) keV·b. An improved information on the total S(E)-factor can be achieved possibly using a 4π-summing crystal. Such an experiment is presently underway at the LUNA facility.

[1] U. Schröder *et al.*, Nucl. Phys. A467 (1987) 240.

[2] C. Angulo *et al.*, Nucl. Phys. A656 (1999) 3.

[3] F. Strieder *et al.*, Nucl. Phys. A718 (2003) 135.

[4] A. Formicola *et al.*, nucl-ex/0312015 (2003).

2.4 Proton inelastic scattering of ^{19}C

Z. Elekes[b)], Zs. Dombrádi, R. Kanungo[b)], H. Baba[a)], Zs. Fülöp, J. Gibelin[c)], A. Horváth[e)], E. Ideguchi[d)], Y. Ichikawa[d)], N. Iwasa[f)], H. Iwasaki[d)], S. Kanno[a)], S. Kawai[a)], Y. Kondo[a)], T. Motobayashi[b)], M. Notani[d)], T. Ohnishi[d)], A. Ozawa[b)], H. Sakurai[d)], S. Shimoura[d)], T. Suzuki[a)], E. Takeshita[a)], S. Takeuchi[b)], I. Tanihata[b)], Y. Togano[a)], C. Wu[b)], Y. Yamaguchi[a)], Y. Yanagisawa[b)], A. Yoshida[b)], K. Yoshida[b)]*

^{19}C is a good candidate for a one–neutron halo nucleus. Several experiments tried to map the structure of ^{19}C by e.g., Coulomb dissociation [1], parallel momentum distribution [2], reaction cross section [3]. The results indicate the halo structure; however, the configuration of the unpaired neutron is still a question. Information on excited levels may help to further clarify the nuclear structure of ^{19}C. We have studied the ^{19}C(p,p') reaction, which is expected to excite possible low-lying states. The experiment was carried out at the RIKEN radioactive isotope separator RIPS [4]. A ^{22}Ne primary beam of 100 pnA intensity and 110 A·MeV energy hit a ^{9}Be production target of 0.8 cm thickness. After momentum and mass analysis, the secondary cocktail beam including ^{19}C at 20% and ^{17}B at 25% was transmitted to a liquid hydrogen target of 190 mg/cm^2 average thickness [5].

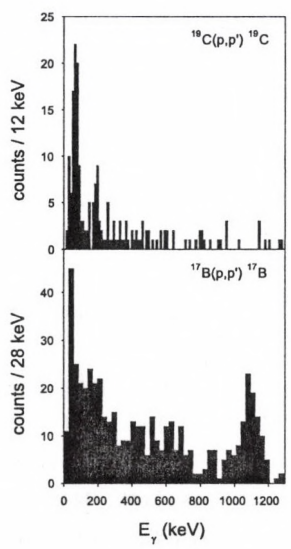

Figure 1 Doppler-corrected spectra of γ rays emerging from ^{19}C(p,p')^{19}C (upper panel) and ^{17}B(p,p')^{17}B (lower panel) reactions.

The incident nuclei could be fully separated from each other by energy loss and time-of-flight measurements. The beam focus was monitored by two PPACs placed upstream of the secondary target. The scattered isotopes were identified using a silicon telescope consisting of three layers with thicknesses of 0.5, 2.0 and 2.0 mm. The ΔE-E method was used for the separation of the different carbon and boron isotopes. ^{19}C and ^{17}B were well separated from other products. The 158 NaI(Tl) scintillator detectors of the DALI2 array [6] surrounded the target and detected the de-exciting γ rays. The threshold was set to 30 keV taking into account the Doppler effect. Figure 1 shows the Doppler-corrected γ ray spectra for ^{19}C and ^{17}B nuclei. Some peaks, including the ones reported earlier for ^{19}C [7] and ^{17}B [8], were observed. Further analysis and assignment of these peaks is now in progress.

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2.5 Excited states in ^{27}F

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^{24}O is the last bound neutron–rich oxygen nucleus, while, adding one more proton to the oxygen isotopes, even ^{31}F is still bound [1]. A sudden lowering of multiparticle multihole states can be an explanation for it [2]. As a consequnce, its traces must also be seen in the lighter F isotopes. For example, allowing for particle-hole excitations to the *fp* shell, a bound excited state in ^{27}F is expected. Therefore, we studied the ^{27}F(p,p'γ) reaction to look for possible bound excited states. A 94 *A*·MeV energy beam of ^{40}Ar bombarded a ^{181}Ta production target. The reaction products were momentum- and mass–analyzed by the RIPS [3] fragment separator. The total intesity was approximately 100 cps having an average ^{27}F intensity of 4 cps.

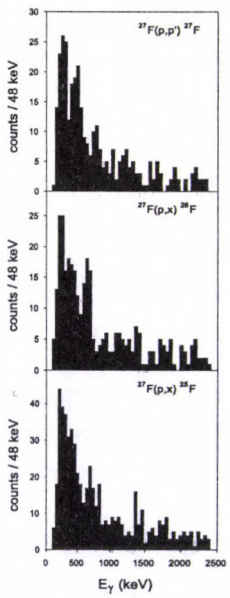

Figure 1 Doppler-corrected spectra of γ rays emerging from ^{27}F(p,p')^{27}F (upper panel), ^{27}F(p,x)^{26}F (middle panel) and ^{27}F(p,x)^{25}F (lower panel) reactions.

The identification of incident beam species was performed by energy loss, time-of-flight and magnetic rigidity ($B\rho$) [4]. A liquid hydrogen target [5] with average areal density of 210 mg/cm^2 served as a secondary target. The incident particles were monitored by two PPACs placed upstream of the target. The scattered particles were detected and identified by a PPAC and a silicon telescope with three layers of 0.5, 0.5 and 1 mm. The Z identification was performed by TOF-energy loss method. Based on ΔE-E information, ^{27}F nuclei were well separated from other products. The new DALI2 setup [6] surrounded the target to detect de–exciting γ rays. In the middle panel of Figure 1 a single peak at around 650 keV can be seen which was found in a recent experiment at GANIL. The upper plot obviously shows 3 peaks at around 450, 750 and 1200 keV. It is straightforward that the sum of the first two peaks gives the energy of the third peak. There is only one unambigous peak at around 700 keV in the lower panel.

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[1] H. Sakurai et al.: Phys Lett. B448 (1990) 1147.
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2.6 Deformation of ^{76}Sr from its β-decay

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The neutron-deficient nuclei with A≈70-80 are the heaviest nuclei one can study in which protons and neutrons occupy the same orbitals (N≈Z). This region of the nuclear chart is characterized by different shape effects such as strong deformation in the ground state, shape transitions and shape coexistence. These three effects are exhibited by the light Sr isotopes, which evolve from sphericity at N=50 to large deformation (presumably prolate) at N=40. The maximum deformation of the region corresponds to the N=Z nucleus ^{76}Sr. The experimental E(2^+)=261 keV [1] for this nucleus indicates, according to the Grodzin's equation, that it is strongly deformed with $|\beta_2| > 0.4$. However, there is no experimental information on the sign of β_2 for ^{76}Sr so far.

According to Refs. [2] and [3], one can study the deformation (including the sign) of the ground state of a particular nucleus by measuring the B(GT) distribution of its β-decay. The aim of our work was to measure the β-decay of ^{76}Sr to obtain its B(GT) distribution with high accuracy to study the deformation of its ground state. With this aim a Total Absorption Spectrometer "Lucrecia" was installed at ISOLDE. It consists of a large NaI cylinder plus some ancillary detectors (left side of Fig. 1). The ^{76}Sr produced and separated at ISOLDE was transported to the centre of the crystal were the complete gamma cascades following the β-decay of ^{76}Sr were measured.

The integrated B(GT) that we obtained after the analysis of the experimental data is shown in the right side of Fig. 1. In the same graph we include the plot of the theoretical calculations for the oblate (β_2=-0.13) and the prolate (β_2=0.41) shapes of ^{76}Sr taken from Ref. [3]. From the figure we can conclude that the ground state of ^{76}Sr is strongly prolate in agreement with the previous experimental indication [1] and theoretical predictions [4].

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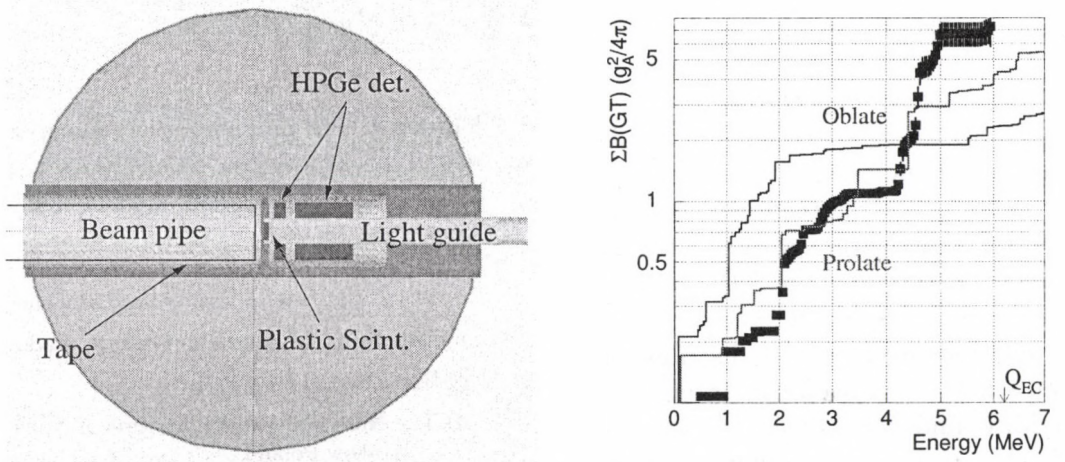

Figure 1 Left: experimental setup. Right: accumulated B(GT) distribution. The results from this work (squares) are compared with the theoretical calculations of Ref. [3] (solid lines).

2.7 First identification of excited states in the $T_z = 1/2$ nucleus ^{93}Pd

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The neutron-deficient nuclei in the $A \approx 80$-90 mass region with $N, Z < 50$ are expected to exhibit a rich variety of features. These nuclei are close to the proton drip line as well as to the $N=Z$ line, and are situated near the doubly magic nucleus ^{100}Sn. The vicinity of the $N=Z$ line allows new correlations to emerge, when the protons and neutrons occupy nearly identical orbitals. In addition to the seniority coupling scheme found in nuclei further from the $N=Z$ line and in which protons and neutrons separately couple to spin 0 in the ground state, the nuclei with T_z close to zero may exhibit an aligned proton-neutron pairing, *i.e.* the protons and neutrons form deuteron-like pairs. When leaving the $N=Z$ line, the importance of this effect is expected to decrease rapidly. With $N=Z+1$, ^{93}Pd is predicted to exhibit the qualities of a transitional nucleus on the boundary between these two extremes.

Excited states in ^{93}Pd were populated via the reaction ^{40}Ca(^{58}Ni,αn) using a beam with an energy of 205 MeV and with an intensity of 5 pnA from the Vivitron accelerator at IReS, Strasbourg. The emitted γ-rays were detected with help of the EUROBALL detector system, at the time of the experiment consisting of 15 cluster type and 26 clover type composite Ge detectors. Charged particles and neutrons evaporating from the compound nuclei were observed by the EUCLIDES Si detector ball and the Neutron Wall array, respectively.

From the γ-ray energy spectra created off-line by requiring coincidences with different combinations of detected charged particles and neutrons several γ-rays were assigned to the decay of the excited states in ^{93}Pd for the first time. On the basis of the measured $\gamma\gamma$-coincidence relations and angular distribution ratios a level scheme has been constructed up to $E_x \sim 7.3$ MeV and $I=(41/2^+)$. The proposed level scheme, shown in Figure 1, is interpreted in relation to shell model calculations performed in the restricted model space of $g_{9/2}$, $p_{1/2}$ for proton and neutron holes. These calculations predict a coupling scheme with aligned neutron-proton pairs to greatly influence the level structure of $N \approx Z$ nuclei at low excitation energies. The results are published in Ref. 1.

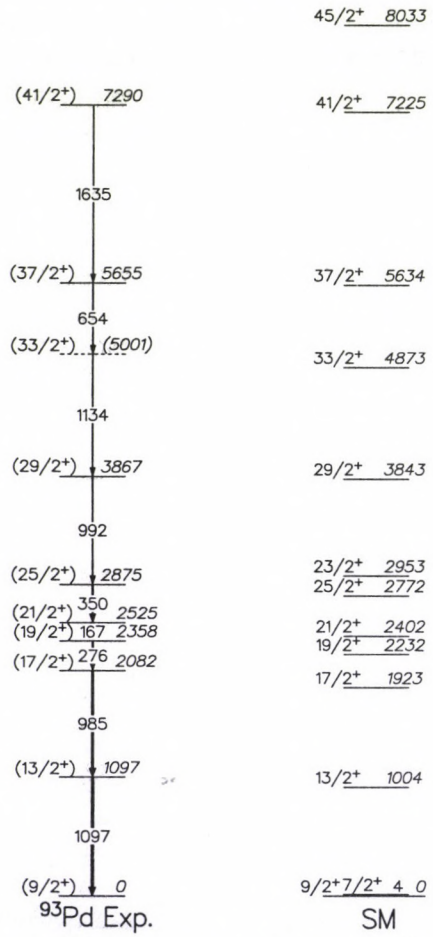

Figure 1. The proposed level scheme of ^{93}Pd populated in the reaction ^{40}Ca(^{58}Ni,αn). The results of shell model calculations are included in the right part of the figure.

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2.8 Chiral twin bands in the ^{105,106}Rh nuclei

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A unique feature of the rotation of triaxial nuclei is the possibility of uniform rotation around an axis which is out of the three symmetry planes of the mean-field ellipsoid. This is in contrast with the rotation of a rigid body. For a triaxial nucleus the projections of the angular momentum vector on the three principal axes of the mean-field ellipsoid can form a left-handed or right-handed system. The two possible linear combinations of these left and right handed systems, which have the opposite chirality, manifest themselves as a pair of degenerate rotational bands [1]. Such chiral twin bands were first observed in the A$\sim$130 region in the odd-odd nuclei [2]. Recently chirality has been reported in an odd-mass nucleus in the same mass region [3] and also in an odd-odd nucleus in a new region of A$\sim$105 Rh isotopes[4], thus confirming the geometrical interpretation and the universality of the phenomenon.

In order to further explore the chirality in the new A$\sim$105 mass region high-spin states in ^{105,106}Rh were studied in an experiment using the Euroball γ-ray array combined with the DIAMANT charged-particle detector system, which was developed in CENBG-ATOMKI collaboration. The high-spin states were populated in the ^{96}Zr(^{13}C,pxn) reactions at two beam energies: 51 MeV and 58 MeV. The target consisted of a stack of two metallic foils, each of 560 μgm/cm^2 enriched to 85% in ^{96}Zr. The events were recorded on magnetic tapes and analysed off-line. To select the Rh channels in the analysis, only the γ-rays detected in coincidence with one proton have been used.

The level schemes of the studied nuclei were constructed based on triple-coincidence relations between observed γ-rays, as well as energy and intensity balances using the Radware analysis package [4]. The spins and parities of the states were determined from DCO and linear-polarization analysis. Chiral twin bands have been found in both ^{105,106}Rh nuclei, thereby establishing a new region of chirality together with the known ^{104}Rh case [5]. Figure 1 shows the twin bands observed in ^{105}Rh. These data provide the first evidence for a chiral structure in an odd-mass nucleus in this mass region.

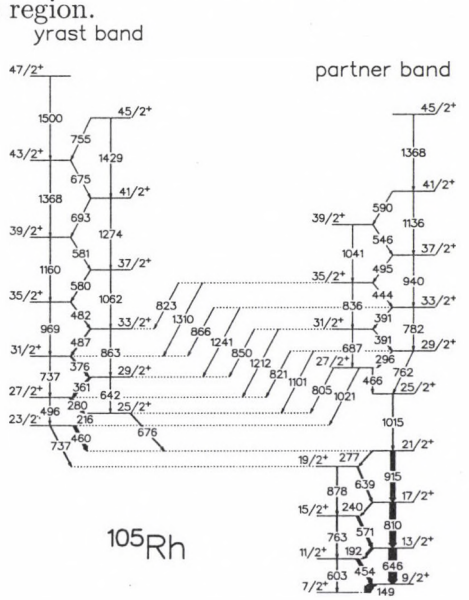

Figure 1. Partial level scheme of ^{105}Rh showing the observed chiral twin (yrast and partner) bands

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2.9 Terminating bands in ^{123}Cs

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The terminating bands can be grouped into three categories on the basis of the energy cost for the nucleus to achieve the last units of angular momentum before termination. These three types of the band termination are called favoured, rigid rotation-like and unfavoured termination, respectively when the energy cost is smaller, equal or larger than that of a rigid rotor reference. In the majority of the experimentally observed cases only one type is found in a particular nucleus. Configuration dependent Nilsson-Strutinsky cranking calculations (CNS) predict favoured band terminations near spin $35\hbar$ and unfavoured band termination near $45\hbar$ in ^{123}Cs for different configurations.

High-spin states in ^{123}Cs were populated using ^{64}Ni(^{64}Ni,p4n) reaction at a beam energy of 265 MeV. The beam was provided by the 88-Inch cyclotron at Lawrence Berkeley National Laboratory. The γ rays following the reaction were detected by the Gammasphere spectrometer. At the time of experiment the array was equipped with 100 Compton-suppressed Ge detectors. The ^{64}Ni target was a foil of 0.476 mg/cm^2 thickness enriched to 96.5%. The data were written to tape in list mode with a condition that at least six or more Compton-suppressed Ge detectors and 15 or more 'modules' were in coincidence. A module is defined as a unit consisting of a Ge detector together with the BGO scintillators surrounding the Ge crystal which act as antiCompton shield. After presorting and setting prompt time gates a total of 1.2×10^9 events with Ge-fold ≥ 4 remained for further analysis.

A new level scheme of the nucleus has been constructed using the coincidence relations with the help of the Radware analysis package. The spins of the observed levels have been derived from the measured DCO ratios. New bands have been observed and the previously known bands extended to higher spins up to spin $71/2\hbar$. The observed bands agree well with the CNS predictions. The good agreement enabled us to assign configurations to the bands at high spins. According to these assignments we have found several favoured band terminations in the spin $\sim 35\hbar$ region. Bands that are predicted to terminate above spin $40\hbar$ have been also observed, however their termination have not been reached in this experiment.

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2.10 Beta decay of ^{148}Dy: confirmation of the Gamow-Teller resonance by means of total absorption spectroscopy

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In heavy nuclei there are only a few regions where the Gamow-Teller (GT) strength is expected to lie within the Q_β window. Above the particle stable N∼Z nuclei these cases are mainly limited to the nuclei where GT decay involving the $\pi h_{11/2} \rightarrow \nu h_{9/2}$ or the $\pi g_{9/2} \rightarrow \nu g_{7/2}$ transitions can occur inside the window. In this work we present results of our study of the β-decay of ^{148}Dy using the total absorption technique. The use of this technique can be justified in this case not because of the large Q_{EC} value of the decay, but because of possible weak feeding and fragmentation of the feeding that remained undetected in high resolution studies [1]. In [1] the existence of a Gamow-Teller excitation populated in the β-decay was shown experimentally at an excitation of 620 keV, but the question if there is β-feeding at higher excitation remained unanswered.

The ^{148}Dy parent nucleus was produced mainly through the ^{93}Nb(^{58}Ni,3p) fusion-evaporation reaction. The ^{58}Ni beam, accelerated by the GSI-Unilac, had an energy of the 5.3 MeV/u. The recoiling nuclei were stopped and ionized in either thermal or FEBIAD ion sources, then extracted and separated in the GSI On-line Mass Separator. The mass-separated activity was deposited on a tape of a transport system with a differential pumping which allowed to transfer the radioactive sources from the mass-separator vacuum to the atmospheric pressure. The samples were collected for 400 s, transported to the measuring site (the GSI Total Absorption Spectrometer [2]), where they remained for 400 s for measurement until the next sample was collected.

Our results show that the large feeding (∼ 96 %) to the 620 keV state is precisely reproduced by our measurement. An interesting result is that states 4^- (109 keV), 2^+ (178 keV), $(3,4)^-$ (195 keV), $(2,3)^-$ (658 keV), and 2^-,$(1)^-$ (795 keV) observed in ref. [1] with measurable feeding practically do not receive feeding according to our analysis. Similarly states $(2,3)^+$ (281 keV), and 2^-,$(1)^-$ (951 keV) also receive less direct feeding than observed in [1]. In the range of 1540 keV to the Q_{EC} we have detected a total feeding of 1.6 % to be compared with the high resolution result of 0.81 % assigned to the last three levels detected in this experiment 1^-,$(0)^-$ (1643 keV) 0.24 %, 1 (1828 keV) 0.05%, 1^-,$(0)^-$ (1841 keV), 0.52%. Within the precision of the 40 keV binning of our analysis these states receive 0.52 %, 0.16 % and 0.35 % feeding respectively. The remaining 0.6 % is assigned to levels that exist in the 1380-1640, 1700-1780, 2020-2220 and 2460-2540 keV energy ranges of excitation with β-feeding intensities of 0.21%, 0.07 %, 0.26 %, and 0.008 % respectively.

Our new experimental results are in line with the theoretical calculations of [3] since the total strength within the Q_{EC} window does not change much compared to [1]. More relevant results of our study are the change in the distribution of the strength among the different weakly populated levels when we compare our feeding distribution with the one of Kleinheinz *et al.* [1] and the confirmation of the existence of weakly fed levels at higher excitation. This result reflects the fact that the higher lying levels do not mix strongly with the Gamow-Teller giant state at 620 keV excitation.

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2.11 Gamma-decay of the isobaric analog resonance in ^{208}Bi

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Spin-isospin excitation modes in nuclei such as the Isobaric Analog States (IAS), the Gamow-Teller (GT), and spin-dipole (SD) excitations have intensively been studied both experimentally [1] and theoretically [2] in a broad region of the nuclear landscape. Study of their decay properties allows one to check their microscopic (particle-hole) structure. Experimentally, the direct proton decay of these states have been studied see eg., [3]. Another means to reveal their microscopic structure is to study their electromagnetic decay properties, which hase been stressed recently [4].

In our previous work some γ-decay of the IAS, GT and SD have been observed in ^{208}Bi [5]. The giant resonances were excited in (^{3}He,t) reactions at KVI Groningen with 177 MeV ^{3}He beams, which produced high background in the γ-ray spectrometers constraining the beam current. Although the statistics was low we could identify eg. a 9 MeV gamma-decay line from the IAS to a low lying (5.9 MeV) satellite of the GT resonance [6].

The aim of the present experiment was to excite the IAS with low energy proton capture on ^{207}Pb and observe their γ-decay in a cleaner way. The experiment was carried out at ATOMKI Debrecen. A proton beam of 11.62 MeV from the 103 cm isocronous cyclotron was used to bombard the self-supporting metallic ^{207}Pb target with a thickness of 1.6 mg/cm^2 in order to excite the isobaric analog resonance.

The excitation function for the proton inelastic scattering to the 0.569 MeV ($5/2^-$) state, which nicely shows the isobaric analog resonance, was measured previously between 11.35 and 11.85 MeV in order to calibrate the energy (analyzing magnet) of the accelerator.

The gamma-decay of the IAS was studied with a 5" x 5" NaI(Tl) detector and three Ge clover spectrometers equipped with BGO anti Compton schields [7]. The data collection and monitoring have been performed with a recently developed VME based multiparameter data acquision system. About 100 million gamma-gamma coincidence events were recorded between the NaI(Tl) (1MeV $< E_\gamma <$ 30 MeV) and the clover detectors (0.1 MeV $< E_\gamma <$ 20 MeV) in order to get information for the branching ratio of the 9-MeV, dirèct gamma decay line and for the gamma-decay of the 5.9 MeV satellite GT resonance in ^{208}Bi. The analysis of the data is in progress.

a) KVI, Groningen, The Netherlands.

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2.12 Deformation-dependence of nuclear clusterization: I. Light nuclei

J. Cseh[a], *A. Algora*[a], *P.O. Hess*[b]

Recently much attention has been paid to the super- and hyperdeformed states of nuclei, in general, and to their relation to cluster-configurations, in particular. The U(3) selection rule [1] seems to be especially suitable for the investigation of the allowed and forbidden cluster-configurations. If the nuclear states in question can be characterised by a single irreducible representation of U(3), which is a relatively good approximation for light nuclei (for the ground state as well as for the super- and hyperdeformed states), then this selection rule is easy to apply. For medium and heavy nuclei, however, the U(3) symmetry-breaking interactions are very strong, therefore, they mix the states of different U(3) symmetries. Nevertheless, even in this case an effective (or average, or quasidynamical) U(3) symmetry may survive [2], and as a consequence a selection rule can be formulated.

Based on the application of the (real or effective) U(3) selection rules we have investigated the deformation-dependence of the allowed cluster-configurations both in light and in heavy nuclei. In particular, we have considered ^{36}Ar, for which the superdeformed state has recently been observed experimentally [3], and a theoretical prediction exists for its hyperdeformed state, too [4]. The excitation quanta of the states and their U(3) symmetries are shown in Table 1, while the result of the U(3) selection rule is given in Table 2.

a) MTA ATOMKI, Debrecen

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Table 1. The U(3) quantum numbers of the ground state, superdeformed state and hyperdeformed state of the ^{36}Ar nucleus.

State	$\hbar\omega$	$[n_1, n_2, n_3]$
Ground	0	[20,20,12]
Superd.	4	[32,12,12]
Hyperd.	12	[48, 8, 8]

Table 2. The allowed and forbidden binary cluster configurations (indicated by their mass-number) of the ground, superdeformed and hyperdeformed states of ^{36}Ar. The clusters are supposed to be in their ground states.

State	Allowed	Forbidden
Ground		18+18
		19+17
		...
		22+14
		23+13
	24+12	
	25+11	
	...	
Superd.		18+18
		19+17
		...
		22+14
		23+13
	24+12	
	25+11	
	26+10	
	27+9	
		28+8
		29+7
		...
Hyperd.	18+18	
	19+17	
	...	
	26+10	
	27+9	
		28+8
		29+7
		...

2.13 Deformation-dependence of nuclear clusterization: II. Heavy nuclei

A. Algora[a], *J. Cseh*[a], *P. O. Hess*[b]

Based on our earlier work on the extention of the SACM (Semimicroscopic Algebraic Cluster Model) to heavy nuclei we have recently studied the effect of the deformation on the possible clusterizations of ^{232}Th.

To look for structural effects in the fission process of ^{232}Th we have applied the U(3) selection rule [1]. The U(3) effective representations, used to characterize the clusters and the parent nucleus, were determined according to the procedure outlined in [2].

One question of particular interest that can be addressed in this framework is if the ^{100}Zr + ^{132}Sn clusterization is an allowed one. This clusterization is located at the maximum of the mass distribution of the fission of ^{232}Th. Another reason for studying this particular clusterization is that in [3] it was shown that the structure of the third minimum in ^{232}Th corresponds to a bi-nuclear configuration involving a spherical heavy fragment around ^{132}Sn and a well deformed lighter fragment around ^{100}Zr.

In a first step we have studied if this clusterization is allowed assuming that the parent nucleus and the clusters have ground state deformations (^{232}Th ($\beta_2 \sim 0.2$), ^{100}Zr ($\beta_2 \sim 0.36$), ^{132}Sn ($\beta_2 \sim 0.0$)). The U(3) selection rule shows that this clusterization is not allowed. The studied clusterization remains forbidden even if we assume that ^{232}Th is in a hypothetical superdeformed (SD, $\beta_2 \sim 0.6$) or hyperdeformed (HD, $\beta_2 \sim 0.86$) state, keeping the clusters in their ground state deformations.

In a second step we have studied if the ^{100}Zr + ^{132}Sn clusterization is allowed when we change the deformation of the clusters. Considering the high stability against deformation of the double magic nucleus ^{132}Sn, we have changed the deformation of ^{100}Zr. ^{100}Zr can be considered soft against deformation, and it is located in a region of shape coexistence [4]. The results are presented in Figure 1. Assuming ground state deformation for ^{232}Th, the clusterization remains forbidden when we change the deformation of ^{100}Zr. A change occurs when we assume that the ^{232}Th in a SD or in a HD state. In these cases the clusterizations are allowed when the ^{100}Zr has large oblate deformation.

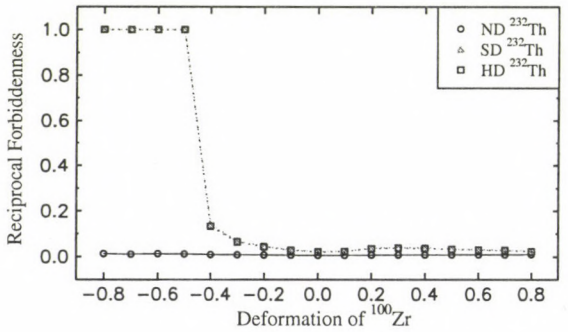

Figure 1. Reciprocal forbiddenness (S) of the clusterization of ^{232}Th as a function of the ^{100}Zr deformation. In this framework allowed clusterizations correspond to S=1, while forbidden ones correspond to S=0. The figure shows our results for different deformations of the ^{232}Th parent state: ND ($\beta_2 \sim 0.2$) circles, SD ($\beta_2 \sim 0.6$) triangles, and HD ($\beta_2 \sim 0.86$) squares. The ^{132}Sn cluster is assumed to be in its ground state deformation ($\beta_2 \sim 0.0$). The results for the SD and HD ^{232}Th cases are very similar.

a) MTA ATOMKI, Debrecen

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2.14 Isospin decomposition of the wave function of 2_1^+ states in selected neutron rich light nuclei

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Recently, several groups reported anomalies in the systematics of the B(E2) values in ^{134}Te [1], ^{70}Ni [2] and ^{28}Ne [3], i.e., the lifetime of the 2_1^+ states in several neutron rich nuclei is much longer than expected. The natural explanation in most cases was the assumption that the wave function of the critical 2_1^+ states is predominantly built up from neutron excitations. Different probes are sensitive to different extents to the excitations of protons and neutrons. As a consequence, from a comparison of transition probabilities observed with different probes, conclusion can be drawn on the role of proton and neutron excitations in different states. For ^{28}Ne and ^{34}Mg, we studied the (p,p'γ) reaction in inverse kinematics. Knowing the B(E2) values from earlier experiments [3,4], the ratio of the neutron and proton multipole transition matrix elements (M_n/M_p), which is a direct measure of the neutron and proton contributions to the excitation, could be determined via the Bernstein formula [5].

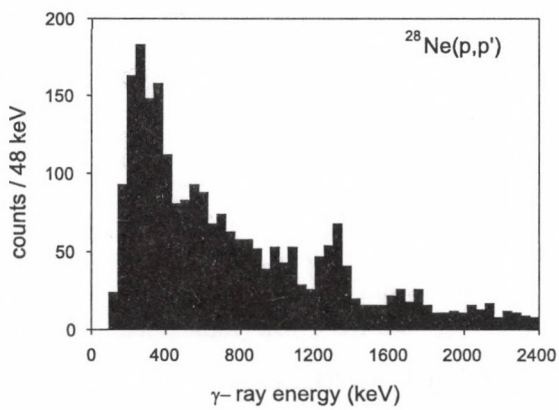

Figure 1 Doppler-corrected spectra of γ rays emerging from ^{28}Ne(p,p')^{28}Ne reaction.

Another experimental way to get the magnitude of proton and neutron excitations is the Coulomb–nuclear interference method [6,7], which was used for ^{16}C nucleus. The absolute values of M_n and M_p could be deduced by the analysis of the angular distribution of the inelastically scattered ^{16}C particles [8]. The details on the experiments can be found in Refs. [8] and [9]. In Fig. 1, the (p,p'γ) spectrum of ^{28}Ne is shown.

The determined ratios of transition matrix elements are 7.6 ± 1.7, 1.0 ± 0.2 and 0.8 ± 0.3 for ^{16}C, ^{28}Ne and ^{34}Mg, respectively. The extremely large value obtained for ^{16}C shows that its first 2^+ state is composed of purely neutron excitations. All the ratios observed clearly deviate from the N/Z rule, which is based on the assumption of volume vibrations, giving rise the possibility to the surface nature of the low energy excitations.

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2.15 The sextic oscillator as a γ-independent potential

G. Lévai, J.M. Arias [a)]

There has been considerable interest recently in the analytic solutions of the Bohr Hamiltonian which describes the collective motion of nuclei in terms of the shape variables β and γ. The origin of these studies lies in the interacting boson model (IBM), which assigns three different dynamical symmetries to three well defined nuclear shapes: spherical vibrator (U(5)), axially deformed rotator (SU(3)) and γ-unstable rotator (O(6)). Recent developments in this field concern transitions between different phases of the IBM phase diagram through critical points, which correspond to rapid structural changes. The first transition of this type associated with an E(5) symmetry was proposed by Iachello [1], and it describes the critical point at the transition from the spherical to the γ-unstable phase. This symmetry is expected to occur in nuclei in which the $V(\beta,\gamma)$ potential depends only on β, and it has a relatively flat shape in this variable. In Ref. [1] this situation was approximated with the exactly solvable infinite square well, and quantitative predictions were made for various spectroscopic properties corresponding to the E(5) symmetry.

Recently we proposed [2] the consideration of the sextic oscillator as a γ-independent potential in the Bohr Hamiltonian

$$-\frac{\mathrm{d}^2\phi}{\mathrm{d}\beta^2}+\left(\frac{(\tau+1)(\tau+2)}{\beta^2}+u(\beta)\right)\phi=\epsilon\phi\,, \quad (1)$$

$$u(\beta)=(b^2-4ac)\beta^2+2ab\beta^4+a^2\beta^6\,, \quad (2)$$

where $c=\frac{1}{2}\left(\tau+2M+\frac{7}{2}\right)$ is a constant. The potential defined by (1) and (2) is quasi-exactly solvable, which means that for any non-negative integer value of M, $M+1$ of its solutions can be obtained in an algebraic way. The solutions are written as $\phi_n(\beta)=P_n(\beta^2)(\beta^2)^{c-M-\frac{3}{4}}\exp\left(-\frac{a}{4}\beta^4-\frac{b}{2}\beta^2\right)$, where P_n is a polynomial of order $n\leq M$. Normalizability requires $a\geq 0$, while $a=0$ reduces the problem to the harmonic oscillator. The solutions with $M=0$ and 1 are sufficient to generate the most widely studied levels, i.e. those with $n\equiv\xi-1\leq 1$ and $\tau\leq 3$. The integrals necessary to determine the normalization constants and the matrix elements of E2 transitions can be written in closed form.

The sextic oscillator has much more flexible structure than potentials considered previously: depending on the parameters this potential has a minimum at $\beta=0$ or at $\beta>0$, and might also have a local maximum before reaching its minimum. (It has to be noted though that the potential shape slightly differs for even and odd values of τ, because $\tau+2M$, and therefore c cannot be set to the same value.) Figure 1 shows a potential with a minimum at $\beta>0$ that leads to an energy spectrum imitating that of ^{134}Ba. Comparing the results with the experimental data for ^{134}Ba we found that the sextic oscillator allows a better approximation than the other essentially parameter-free potentials, i.e. the infinite square well and the numerically solvable β^4 potential. We expect that this potential can be used not just at the critical point but it can be useful to model the full shape phase transition from spherical to deformed $\gamma-$unstable nuclei by changing the parameters a and b.

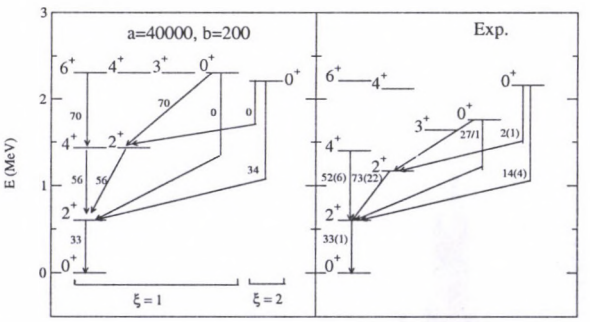

Figure 1. The energy spectrum and the strength of some electric quadrupole transitions calculated with $a=40000$ and $b=200$ (left panel) and the corresponding data for ^{134}Ba (right panel).

a) Universidad de Sevilla, Sevilla, Spain

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2.16 Renormalization-Group Analysis of the Generalized sine-Gordon Model and of the Coulomb Gas for $d \geq 3$ Dimension

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A renormalization-group analysis of the generalized sine-Gordon model (GSGM) and that of the equivalent Coulomb gas (ECG) have been pursued for $d \geq 3$ dimensions [1]. Renormalization of the GSGM and that of the related models (e. g. XY model) in $d \geq 3$ dimensions are of particular interest with regard to the numerous physical applications. In low-temperature physics the three-dimensional XY model (isotropic and anisotropic) was used to study the phase transitions in the three-dimensional flux-line lattice. The three-dimensional XY model can also help us in understanding the flux motions in superconductors with extremely high anisotropy; these have been observed in recent experiments.

The RG equations for the GSGM and the ECG are derived in two ways: (i) by means of Wegner's and Houghton's (WH-RG) method in the local-potential approximation and (ii) by the real-space RG (RS-RG) in the dilute-gas approximation. These different approaches complement one another: the WH-RG applied to the GSGM is better suited to determine the IR behaviour of the system, whereas the RS-RG applied to the ECG is able to better represent the non-linearities which influence the UV scaling. It has been shown that the leading-order terms of the flow equations obtained by these methods agree well. Taking as an example the 4-dimensional GSGM, we have demonstrated numerically that the blocked potential tends to a constant effective potential, independent of the field-variable, in the IR limit. This behaviour is in agreement with the global requirements on the RG flow that constrain the effective potential to be periodic and convex at the same time. Comparing the evolution of the periodic blocked potential to that of a polynomial potential obtained by a Taylor-expansion of the bare periodic potential, we show that a violation of the periodicity would lead to a completely incorrect IR scaling.

Because the GSGM, the ECG and the XY-model belong to the same universality class, the determination of the RG flow of these models for the three-dimensional case via two different, complementary methods in the UV regime enables us to compare the UV scaling with that of a three-dimensional vortex gas (VLG). It has been established that one may transform the flow equations for the ECG to a form very close to that of the flow equations for the VLG, if only the leading order terms are kept. Nevertheless, the negative fugacity one needs to introduce and the different explicit scale-dependences occurring in the two sets of the flow equations do not enable one to make any definitive conclusion regarding the question whether the VLG and the three-dimensional Coulomb gas belong to the same universality class.

Acknowledgements

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2.17 Construction of virtual states

J.Zs. Mezei and R.G. Lovas

The discrete eigenstates of a Hamiltonian can be identified with poles of the S-matrix of the system. The theoretical methods to describe few-body bound states are mostly variational. The methods for the localization of unbound states mostly imitate the bound-state methods. The analytic continuation in the coupling constant (ACCC) combined with correlated Gaussian bases is a well-established method for extrapolation of bound states [1].

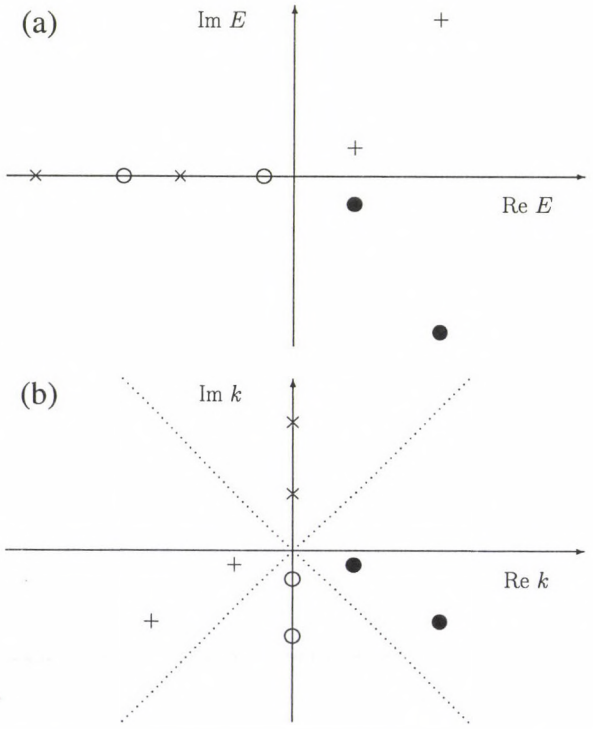

Figure 1. Typical positions of the bound-state (×), resonance (•), antiresonance (+) and virtual-state (○) poles in the complex energy plane (a) and in the complex momentum plane (b)

The poles of the S-matrix of a potential problem with short-range attraction (and a barrier) are situated as in Figure 1. We are now concerned with virtual states, which are useful tools in describing complex systems [2].

We performed calculations for a model of two identical particles of unit mass interacting via $V = -2.384e^{0.16r^2} + 1.0e^{0.04r^2}$ (a.u.). The virtual-state energy and wave number obtained by extrapolation of s-wave bound-state variational solutions are $E = -0.003405$ a.u. and $k = -i0.05835$ a.u., respectively. (The exact [3] values are $E = -0.003408$ a.u. and $k = -i0.05838$ a.u.) The ACCC radial wave function defined as $u(r) = r\psi(r)$, where $\psi(r)$ is the full wave function, is shown in Figure 2, and the exact wave function is very similar, except that there are no ripples beyond 10 fm. The virtual-state wave function is almost as accurate as the resonance wave functions calculated with similar extrapolations [4].

These facts point to the usefulness of this method.

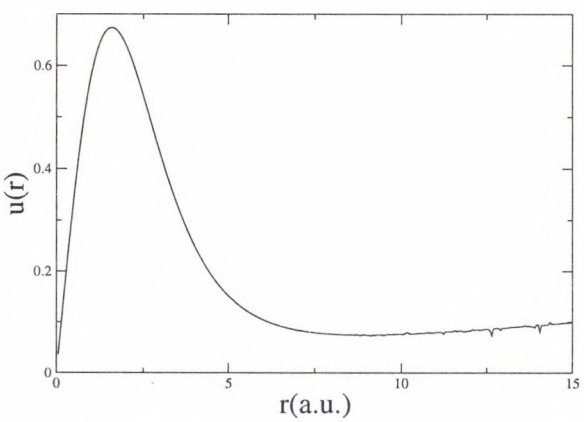

Figure 2. The wave function of the virtual state

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[3] FORTRAN codes: GAMOW written by T. Vertse and RADSCH written by A.T. Kruppa.

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2.18 Perturbative Quantum Chromodynamics

Z. Trócsányi

Higgs production in association with a jet of high transverse energy with a subsequent decay into two isolated photons, $pp \to H + \text{jet} \to \gamma\gamma + \text{jet}$, is considered a very promising discovery channel for a Higgs boson of intermediate mass ($100\,\text{GeV} \leq m_H \leq 140\,\text{GeV}$). The main background to this signal is the $pp \to \gamma\gamma + \text{jet}$ channel, where the photons are isolated. In this channel the signal is a small and narrow peak on a flat background. In order to optimize the selection and isolation cuts for the experimental search one usually uses a Monte Carlo event generator, which however, does not take into account the QCD radiative (NLO) corrections. These corrections are large and strongly dependent on the photon isolation parameters [1], therefore, cannot be ignored in the analysis.

In order to assess the dependence of the radiative corrections on the isolation parameters, we wrote a partonic Monte Carlo program which employs the dipole subtraction method as implemented in the `NLOJET++` package [2]. In perturbation theory beyond leading order, the isolated photon cross section is not infrared safe. To define an infrared safe cross section, one has to allow for some hadronic energy inside the photon isolation cone. In a parton level calculation it means that soft partons up to a predefined maximum energy are allowed inside the cone. This is also natural in the experiment: complete isolation of the photon is not possible due to the finite energy resolution of the detector.

To implement the photon isolation in the computation, we used a 'smooth' isolation prescription at the parton level [3], which means that the energy of the soft parton inside the isolation cone has to converge to zero smoothly if the distance in the $\eta - \phi$ (rapidity-azimuthal angle) plane between the photon and parton vanishes. Explicitly, the amount of hadronic transverse energy $E_\perp$ (which in our NLO partonic computation is equal to the transverse momentum of the possible single parton in the isolation cone) in all cones of radius $r < R_\gamma$ must be less than

$$E_{\perp,\max} = \varepsilon p_{\gamma\perp} \left(\frac{1 - \cos r}{1 - \cos R_\gamma} \right)^n . \qquad (3)$$

Fig. 1. shows the perturbative prediction at the leading- and NLO accuracy. The leading order prediction (dashed line) is independent of the isolation parametes. The radiative corrections are rather large and strongly dependent on the isolation parameters. The milder the photon isolation (small R_γ and large ϵ), the larger the correction. In particular, if R_γ takes the value of 0.5, as commonly used in experiments, the corrections are larger than 100 %, indicating that the fixed order perturbation theory is not reliable, and multiplying the leading order cross section with a fixed K factor (the ratio $\sigma^{\text{NLO}}/\sigma^{\text{LO}}$) is not suitable to take into account the effect of higher order corrections.

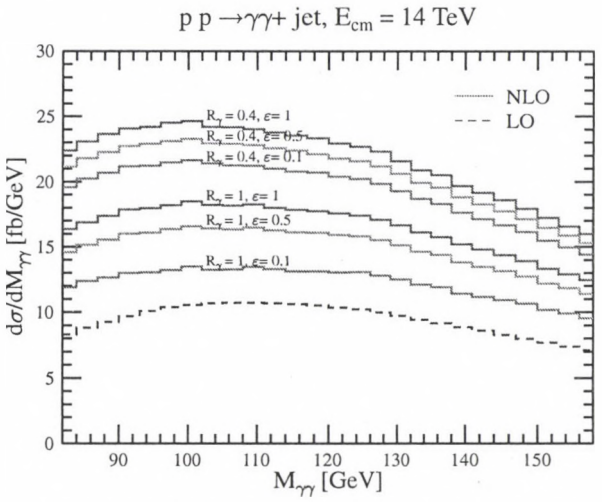

Figure 1. Differential distribution of the two-photon invariant mass.

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2.19 Shell model representation with antibound states

R. Id Betan[a,b], R.J. Liotta[a], N. Sandulescu[a,c] and T. Vertse,

A unified shell model scheme is introduced that evaluates simultaneously the contributions of bound single-particle states, Gamow resonances and antibound states to processes occuring in the continuum part of nuclear spectra.

Long time ago Berggren introduced a complete system of single particle basis functions (Berggren repesentation) composed of bound states, complex energy resonant sates (Gamow states) and a complex continuum of scattering states along a complex contour [1]. However the first attempts to use the Berggren representation in the originally suggested form for shell model desciption of many body resonances in the complex energy plane has been done only recently [2]. Now we made a further step in extending the Berggren representation. We included also antibound poles of the S-matrix into the basis [3]. In this work the shell model in the complex energy plane [2] was further generalized in order to use the extended Berggren representation. The unique feature of this approach is that it allows us to study the role of the antibound pole and the corresponding complex continuum separately. In this approach the role of the antibound states were studied in weakly bound nuclei. The method has large flexibility in choosing the single particle basis. By changing the single particle contour we can change the members of the Berggren representation used. If the contour is along the real energy axis then we use the standard complet set of the bound states and real energy scattering states. Drawing the contour in the third quadrant of the complex k plane we can include certain Gamow resonances into the basis. If the contour passes over the negative imaginary k-axis we can also include antibound state and use the extended Berggren representation.

We applied the model to study the structure of the halo nuclei ^{11}Li and ^{72}Ca. In both cases we considered two valence neutrons outside cores ^{9}Li and ^{70}Ca, respectively. The effects of the core were simulated by phenomenological Woods-Saxon potentials in which weakly bound antibound poles appear in the $l = 0$ partial wave. The interaction between the neutrons has a separable form and the strength was adjusted to reproduduce the measured (or estimated) energies of the corresponding ground states. The use of separable interaction simplified our calculations considerably and we were able to use dispersion relation for calculating the complex two particle energies (and wave functions) instead of diagonalizing the two particle Hamiltonian. It was found that an antibound state lying close to the threshold has a fundamental importance in building up the halo in the nucleus. We found also that in the ground state of the ^{11}Li the large contribution of the antibound pole is cancelled to a great extent by that of the complex continuum.

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3.1 Laser Spectroscopy of Antiprotonic Helium Atoms

D. Horváth, B. Juhász (ASACUSA collaboration)

In 2003, laser spectroscopy studies of antiprotonic helium atoms ($\overline{\mathrm{p}}-\mathrm{e}^- - \mathrm{He}^{2+} \equiv \overline{\mathrm{p}}\mathrm{He}^+$) and antiprotonic helium ions ($\overline{\mathrm{p}} - \mathrm{He}^{2+} \equiv \overline{\mathrm{p}}\mathrm{He}^{2+}$) were carried out at the Antiproton Decelerator (AD) of CERN. The experiments used both the direct AD antiproton beam (energy: 5.3 MeV) and the decelerated beam (energy: 20–120 keV); the latter was produced using the Radio Frequency Quadrupole Decelerator (RFQD), a unique device which both decelerates and focuses the antiproton beam.

In 2003, we made new measurements on the hyperfine splitting of one metastable state of the antiprotonic helium atom using a laser-microwave-laser triple resonance method [1]. Even though we measured this splitting before, we hoped that we could improve the accuracy of the measurement by *i)* increasing the length of the observation time window, *ii)* decreasing the density of the helium gas target thereby reducing the collisional broadening, *iii)* using a metal shield to decrease the magnetic field inside the target chamber which could cause line splitting, and *iv)* using a more accurate 10 MHz reference signal synchronized by GPS receiver. Unfortunately, due to the not so good quality of the AD beam (its diameter was too large and its intensity fluctuated too much shot-by-shot) the width of the measured hyperfine lines was not smaller than previously.

We systematically produced and studied for the first time a large number of antiprotonic helium ions. The energy levels of this simple two-body system can be easily and very accurately calculated, therefore it is an ideal subject of laser spectroscopy studies. As a first step, we measured the dependence of the decay rate of several ionic states on the target density, and from the obtained data we determined the collisional quenching cross section of these states. These laser spectroscopy studies can ultimately lead to a better determination of the mass and charge of the antiproton and thus give a more stringent limit on the validity of CPT invariance [2].

We continued the investigation of the temperature dependence of quenching of metastable atomic states in collisions with H_2 and D_2 molecules [3]. According to the theoretical calculations of Sauge and Valiron [4], a state-dependent activation barrier exists for this kind of quenching reaction, which means that the quenching cross section σ_q can be expressed as the sum of an Arrhenius term and a temperature-independent term:

$$\sigma_q = \sigma_0 \exp(-E_b/kT) + \sigma_t, \qquad (1)$$

where σ_0 is the cross section at infinitely high temperatures, E_b is the height of the activation barrier, k is the Boltzmann constant, T is the temperature, and σ_t is the cross section of tunnelling of the colliding molecule through the activation barrier. In 2002, we could only measure the temperature dependence of the quenching cross section of one antiprotonic state with H_2 in detail [3]; now we measured another two states. In case of one state, the obtained data could be perfectly described by the above equation, while the other – barrierless – state showed a completely different behaviour: its quenching cross section increased with decreasing temperature and it was proportional to the inverse collisional velocity $1/v$. This dependence is in agreement with the Wigner threshold law of exothermic reactions involving neutral particles.

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3.2 Angular differential cross sections for ionisation of helium by proton impact

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Angular differential cross sections for ionization of helium are calculated within the framework of different theoretical approaches and compared with experimental data. As projectiles we consider H^+ with an energy of 500 keV [1]. Beside the Continuum Distorted Wave (CDW), Continuum Distorted Wave Eikonal Initial State (CDW-EIS), first Born approximation and Classical Trajectory Monte Carlo (CTMC) methods a new aspect is presented calculating angular differential cross sections by solving coupled-channel equations.

All technical details about our single-centre coupled-channel method can be found in [2,3] where we successfully calculated total single- and double-ionisation cross sections of helium in heavy ion collisions. The coupled-channel method is a non-perturbative description involving configuration interaction wave function. As basis set we use Slater like orbitals to describe bound states of helium and regular Coulomb wave packets to have a finite approximation about the single and double electron continuum. A wave package is constructed by an integral over the radial Coulomb wave function in a well defined finite energy interval. The motion of the projectile is described with a constant speed straight-line trajectory. As projectile-electron interaction we applied the non-relativistic time-dependent Coulomb potential. With the help of the density operator we calculate the angular differential ionisation probabilities and with an additional integration over the impact parameter we get the angular differential cross sections. According to our knowledge there is no angular differential cross section calculation for helium in proton or heavy ion projectile impacts using a time-dependent coupled-channel calculations until now. Fig 1. shows the angular differential cross section for ejected electrons emitted in 500 keV proton helium collisions.

At low scattering angles $\Theta < 40°$ no experimental data are available. The CTMC gives the highest estimation for zero degree following CDW and CDW-EIS models. The coupled channel method with the first Born approximation give the lowest cross section for zero degree. At about 60° scattering angle all the quantum mechanical models have a maxima. CDW and CDW-EIS models explain this phenomena with the Binary Encounter Approach (BEA). Above 80° scattering angle all the quantum mechanical models give satisfactory accordance with experimental data and CTMC underestimates the cross sections with 30 %.

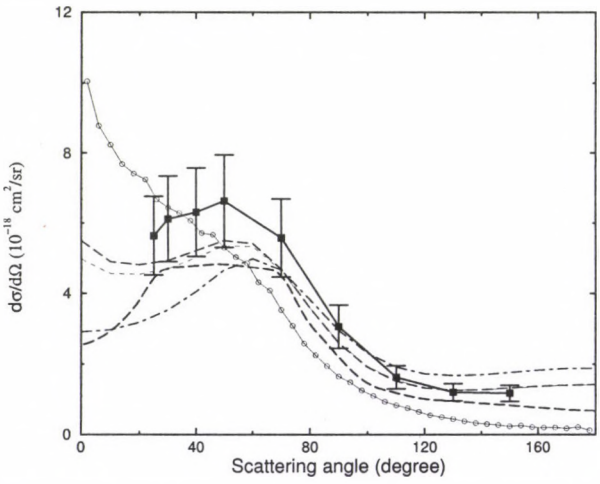

Figure 1. Angular differential cross section for ejected electrons emitted in 500 keV proton helium collisions. Experiment: solid square: [1], Theory: thick dashed line: Coupled-channel calculation, dash-dotted line: First Born approximation, long thin dashed line: CDW, thin dashed line: CDW-EIS, solid circle: CTMC.

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3.3 Double K shell ionization of Mg and Si induced in collisions with C and Ne ions

M. Kobal[a)], *M. Kavčič*[a)], *M. Budnar*[a)], *J.-Cl. Dousse*[b)] *and K. Tőkési*

The X-ray satellite and hypersatellite spectra of Mg and Si solid targets bombarded by 34 MeV C and 50 MeV Ne ions were measured using high-resolution crystal diffractometry. The energy resolution of approximately 0.5 eV enabled us to separate contributions corresponding to states with different numbers of K and L shell vacancies. The relative intensities of satellite and hypersatellite lines were determined by fitting the measured spectra with lineshapes calculated using the GRASP92 computer code. We associated the measured X-ray yields with the production yields of initial states by considering total decay schemes of initial states. The decay schemes were also used to limit parameters of the fit, namely the relative intensities of contributions to each K satellite and hypersatellite, and K intensities which overlap the K hypersatellites and can not be resolved directly from the measured spectra. Initial state production yields were used to determine the probability for L shell ionization and the double to single K shell ionization ratio. The experimental values were compared to theoretical predictions obtained within the independent electron model using single electron ionization probabilities calculated by the three body classical trajectory Monte-Carlo (CTMC) method. While the double to single K shell ionization ratio matched the CTMC-based predictions, the CTMC-based L shell ionization probabilities were approximately two times higher.

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3.4 Angular distribution of scattered projectiles following double electron capture processes at low energy C^{4+} and helium collisions

M. Hoshino[a,b], *Y. Yamazaki*[a,c] *and K. Tőkési*

The recent availability of sources for slow highly charged ions (HCI), namely electron cyclotron resonance (ECR) and electron beam ion sources (EBIS) has led to a flurry of research activities, both experimental and theoretical, in the field of HCI-atom interactions. One of the interesting classes of these investigations is the study of multi-electron capture processes [1,2]. On the most fundamental level, its importance is derived from the applications in many fields, e.g. astrophysics, fusion research, atmospheric science, and plasma diagnostics. Angular differential cross section measurements provide also information from the interaction potential curves.

In this work a four-body classical trajectory Monte-Carlo (CTMC) method [3] is used to calculate the double electron capture probabilities in 470 eV C^{4+} and He collisions. The four particles have the corresponding masses and charges and the forces acting among the four bodies are taken to be pure Coulombic ones. The interaction between the two active electrons of the Helium atom is neglected. The impact parameter of the projectile and the orientation and velocity of the electrons moving around the target nucleus are randomly selected according to the Monte Carlo method. The binding energies of the electrons in the He atom are chosen conveniently 2 a.u. and 0.903 a.u., respectively. To distinguish between the various final states, the exit channels are tested at large distances from the collision center.

The angular distribution of scattered projectiles following double electron capture processes at low energy C^{4+} and helium collisions show an intense peak at 0° applying the 4-body CTMC method. This result is surprising at first sight because due to the slow projectile velocity we expected that the interaction time is plenty large enough creating large angle scattering for projectile. To solve this unexpected finding we calculated the contour plot of the double electron capture probabilities as a function of impact parameter (b) and scattering angle (θ). According to our calculations, when the impact parameter is small (around 0°) the scattering angle is also small. At $b = 0$ the scattering angle is 0°. We conclude that the dominant contribution of double electron transfer at the range of small impact parameters arise from the so called "knock-on" collisions, i.e. the C atoms remain almost rest after the collisions and the He^{2+} "scatter" into 0° (recoil effect).

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3.5 Angular dependent PCI effect on photoionized Ar LMM Auger line shape

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We have studied the effect of post collision interaction (PCI) on the Ar LMM Auger line shape after photoionization as a function of the emission angle. The photon energy was varied between 320-440 eV. The calculations were made on the basis of eikonal approach. The effect of PCI on the line shape is described by the average asymmetry parameter [1]. The input data of these calculations are differential cross sections of the photoelectrons, it is given by the equation:

$$\frac{d\sigma}{d\Omega} = \frac{\sigma_i^t}{4\pi}\left\{1 - \frac{\beta}{2}\left[P_2(\cos\theta) - A\right]\right\} \quad (1)$$

where $A=\frac{3}{2}\cos 2\varphi \sin^2\theta$, $P_2(\cos\theta)$ is the second Legendre polynomial and β is the angular asymmetry- or angular distribution parameter, θ is the polar angle, measured relative to the primary axis, φ is the azimuthal angle, measured between the emission half plane and the electric vector of the linearly polarized synchrotron radiation. The value of β parameter is constant (β=2) for Ne 1s photoionization but for Ar 2p ionization it depends on the photon energy [2]. The experimental Auger electron spectra have been measured with synchrotron radiation on the soft X-ray beamline I411 at MAX lab, Lund, Sweden. A hemispherical Gammadata-Scienta SES-100 electron analyser combined with a gas cell with small holes for incoming photons and outgoing electrons in the interaction region were used to obtain the electron spectra. All the measurements were done perpendicular to the photon beam ($\theta = 90°$), the angle φ between the Auger emission half plane and the electric vector of radiation was changed in the 0°-90° region.

The detailed results will be published in Ref. [3]. We found a general agreement between calculated and measured peak asymmetries. The most exciting case when the speeds of the photo and Auger electrons are close and because of this reason a strong angular dependence of peak asymmetries is expected. We measured definitely opposite signs of peak asymmetries in the polarization direction ($\varphi = 0°$) and respectively in the perpendicular direction ($\varphi = 90°$). The sign changing must be between 45° and 50°, where the PCI distortion of line shape vanishes (Fig.1).

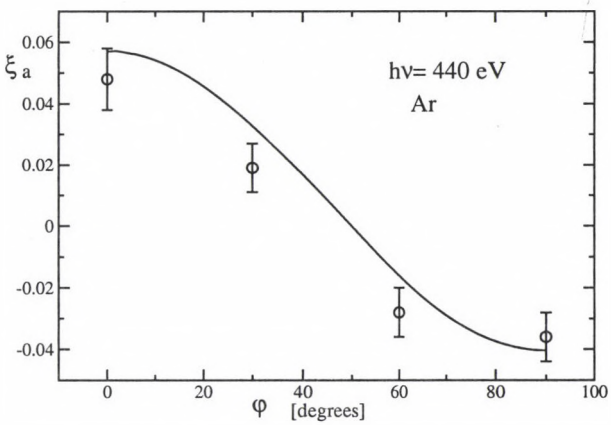

Figure 1. Ar Auger peak asymmetries as a function of the azimuthal emission angle at 440 eV photon energy. Open circle: present experiment, solid line: present theory.

Acknowledgement

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3.6 Ambiguities in multiple ionization x-ray satellite energies

I. Török and T. Papp

Although x-rays have wide applications in elemental analysis, and are also used in determining the masses of elementary particles, like antiprotons, pions, muons and neutrinos, the accuracy of the x-ray databases are still far from assuring that the results are model and equipment independent. Indeed, the majority of x-ray angular correlation and angular distribution measurements yield somewhat unexpected results, that are not in line with the symmetry requirements predicted by the angular momentum and parity conservation rules. The neutrino mass measurements with solid state detectors yielded questionable results, which origin is not yet described.

For consistent use of x-ray spectrometers the proper energy calibration offers some advantages. There are strong discrepancies in the x-ray energy values [1]. The x-ray spectra also contains satellite lines, which presence could be incorporated into the analysis of x-ray spectra, with a possibility of potential improvements. It's inclusion in the energy calibration seems to be unavoidable. We attempt to compile the energies of the KL multiple ionization x-ray satellite lines (e. g. [2]). Such a work could be expected to be a simple exercise, however several ambiguities make such a work difficult. One of them is, that the energy calibration in the source works are different. This leads to several tenths eV ambiguity. Another problem is, that in many cases, the author's interest is focused on the intensity ratios of the spectral components, therefore the energy calibration is missing, or is inaccurate. A third problem arises from the multiple ionization itself: at certain projectiles and bombarding energies the unresolved additional components from higher subshells are different. In the studied cases [1, 2] the M shell contributions caused widening and shifting of the KL^i lines, giving a few eV ambiguity. A fourth problem is that the $K\alpha_1$ and $K\alpha_2$ lines at higher Z values are separated in a good high resolution crystal spectrometer, and the $K\alpha_2$ satellites interfere with the $K\alpha_1$ diagram and satellite lines. At low Z (e. g. Al) the KL satellite spectrum looks like a glove with several fingers. After the $K\alpha$ diagram line come roughly the KL^1, KL^2,..., KL^7 group of lines. At higher Z (eg. Pd) the resolved $K\alpha_1$ and $K\alpha_2$ lines both have their own glove's fingers separately, shifted from each other. May be this is the reason, why we did not find reliable measured E values in this range in the early literature. Nowadays, there are attempts to investigate these higher Z element satellites (see e. g. Fig. 1 in ref. [3]). Here the $K\alpha_2L^2$ and $K\alpha_2L^3$ lines are under the $K\alpha_1L^0$ and $K\alpha_1L^1$ lines. It would be a useful project to measure the multiple ionization satellites of all the elements, using the same apparatus (including accelerator and spectrometer) and the same measuring and evaluation methods, through wide ranges of energies and projectiles. A consistent data body could improve the precision of x-ray analytical measurements.

However, such attempts should overcome the general practice of ignoring the possibility that the x-rays could be polarised. In Maxwell's equations there aren't any specific length parameter, therefore it is expected to be valid for a broad energy range of electromagnetic radiations. While it is a common practice to consider that the visible light is polarised, there are a tendency to ignore such a possibility in x-ray spectroscopy. Generally the x-rays are also polarised, and there are two extrema when they are 100% or 0% polarised. Satellites are expected to be generally polarised [4]. Therefore their measurements with polarisation sensitive devices might benefit from the inspection, whether the extrema of 0% polarisation is fulfilled.

For practical x-ray analytical work, we recommend to use the approximate formulae for the energies [2]. However, it should be noted that recent practicies to use the satellite intensity data for x-ray analitical work could only be considered reliable if the polarisation sen-

sitivity of the diffraction spectrometers are incorporated. Similar difficulties arise for the hypersatellites and in accounting for the chemical effects in the ionization process.

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3.7 State selective single electron capture from noble gas by highly charged ions

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One of the main goals of the recent activity in the field of charge transfer dynamics in collisions of low energy highly charged ions (HCIs) with atoms is to identify state selective (n, l) capture distributions. In the single, double or multiple electron capture processes evoked by HCIs the products generally are in excited states after the collision and can stabilize either by the ejection of Auger electrons or photons. The accurate knowledge of the initial state distribution (ISD) of the HCI is important in a range of astrophysical and laboratory plasma environments, since the ratios of line intensities provide information on the electron temperature and density as well as spatial and temporal distributions in the emitting region of the plasma [1]. Recently a series of the experimental studies of the electron capture processes involving X-ray emission at low projectile energies were presented (e.g. [2]). The motivation of the recent studies is to provide sophisticated state selective (n, l) cross sections for theinterpretation of the measured X-ray spectra.

In this work the ISD for single electron capture (SEC) in the framework of the independent particle model (IPM) is studied by a three-body classical trajectory Monte Carlo (CTMC) method [3-4] and by semiclassical multi channel Landau-Zener (MCLZ) theory [5]. The CTMC model is based on the classical over barrier model (COBM) which is the modern classical description of the electron capture process. The COBM predicts that a single captured electron predominantly populates states with principal quantum numbers $n_d \approx q[(2\sqrt{q}+1)/(2I_T\sqrt{q}(1+\sqrt{q}))]^{1/2}$, where q is the charge of the projectile and I_T is the first ionization potential of the target. It has been established that this formula sucessfully predicts the most probable n state of the capture in most experimental situations. It is however, unable decribe the ISD(n) and ISD(n, l) distributions.

The results of our CTMC and MCLZ calculations for n_d are close to the COBM predictions for the collision systems we initially studied (Ar^{17+} and Ar^{18+} on Ar). We can also conclude that the ISD(n) for the considered collision systems have sharpe and asymmetric Gaussian-like shapes with a narrow full width at half maximum (FWHM). The FWHM becomes larger with increasing the projectile charge q and energy E, respectively. While the predicted values of n_d were close for CTMC and MCLZ calculations there are significant differences in the obtained l-distributions. We belive that, this discrepancy may mainly be caused by the complete negligence of the effect of the rotational coupling terms $vb\langle f|\mathrm{i}L_y|i\rangle/R^2$ in our MCLZ model. The rotational coupling operator L_y couples quasi-molecular states (which dissotiate to the atomic final states) having same spin and different angular symmetry $(\Sigma-\Pi, \Pi-\Delta)$ in accordance with the Wigner's rule. In our future work we are planning to investigate this effect for different HCI collision systems.

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3.8 Experiments and modeling of state selective electron capture in slow HCI collisions

E. Takács[a,d], H. Tawara[a], V. Kharchenko[b], L. Lugosi[c], K. Tőkési, L.P. Ratliff[a], J.D. Gillaspy[a], Cs. Szabó[d], T. Suta

Recently a series of the experimental studies had been carried out at the NIST for the electron capture processes

$$P^{q+} + T \rightarrow P^{(q-1)+*}(nl^{2S+1}L_J) + T^+ \quad (2)$$

(P=$Ne^{9+,10+}$, $Ar^{17+,18+}$, $Kr^{35+,36+}$; T=O_2, Ne, Ar) involving X-ray emission with low projectile energies [1]. The collision systems had been selected to cover a wide range of projectile charges q and target first ionization potentials I_T. These parameters play essential role in determining the initial states distributions ISD of the captured electrons. Therefore a systematic series measurements can aid the theoretical understanding of the capture process. The projectiles were selected to be one ore two electrons systems in order to keep the modeling task simpler.

As our first attempt for the theoretical understandind we were concentrating on Ar^{17+} projectile ions colliding with Ar neutrals. The single K hole initial projectile assured a rather simple X-ray spectrum and the fairly high charge made the collisions different from other previously studied systems.

In the theoretical modeling spectra were generated at the ITAMP by applying a time dependent population calculation method [2]. The ISD(n,l) initial state distributions needed as input parameters were calculated at ATOMKI using two different theoretical approaches. The single electron capture was treated by an CTMC method and by an MCLZ model [Lugosi et al., see this Ann. Rep.]. The comparison of the theoretical and experimental spectra can be seen on Figure 1. The theoretical spectrum based on the CTMC (n,l) cross sections is in good agreement with the experimental one both in the sape and the relative magnitude of the peaks. Using the (n,l) cross sections obtained by the MCLZ model, however, the relative intensities of the higher energy peaks are clearly overestimated.

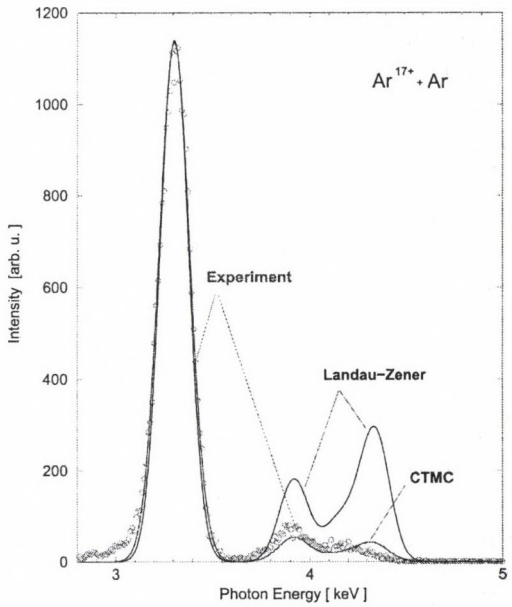

Figure 1. *X-ray spectra generated in Ar^{17+} on Ar collisions.*

We believe that this discrepancy is due to the rotational mixing of Stark states neglected in our calculations as it was previously assumed to be important for these kind collisions. The further investigation of this effect is under way for this and other collision systems.

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3.9 On the energy shift of the ECC cusp: Does the shift really exist?

L. Sarkadi and R.O. Barrachina[a)]

The cusplike "electron capture to the continuum" (ECC) peak appearing in the spectrum of the forward emitted electrons in ion-atom collisions are generally thought to be a divergence. Recently Shah *et al.* [1], however, claimed that "the ECC cusp is indeed a cusp, and not a divergence smoothed by the experiment". These authors measured the ECC cusp for collisions of 10- and 20-keV protons with H_2 and He, and found that the peak was shifted to lower velocity than its expected position (centered on the projectile velocity v). Their classical trajectory Monte Carlo (CTMC) calculations supported the observation. On the basis of an earlier theoretical work [2] they explained the effect as a result of a long-range residual interaction of the electron with the target ion.

In the present work we also carried out CTMC calculations (for the case of 20-keV protons on He) by which we demonstrated that the shift really exists but its value depends on the angular window of the electron detection (i.e., the acceptance angle θ of the electron spectrometer used in the experiment). Fig. 1 shows the results obtained from evaluation of 3×10^8 collision events. One can see that the shift decreases with decreasing θ. The extrapolation of the data to $\theta = 0$ clearly shows that the shift disappears at infinitely small angular window.

We note, however, that a small residual shift should exist even at $\theta = 0$ due to the energy loss of the projectile in the ionization process. Furthermore, the divergence is smeared out by the scattering of the projectile, therefore the cross section is indeed finite at $v_e = v$. In the framework of the general theory of the final-state interaction theory of cusp formation [3] we showed, however, that this effect could only be observable if the acceptance angle of the spectrometer were reduced to a prohibitively small value of 0.06° at 10 keV impact energy (the experiment in [1] was carried out with $\theta = 1.5°$).

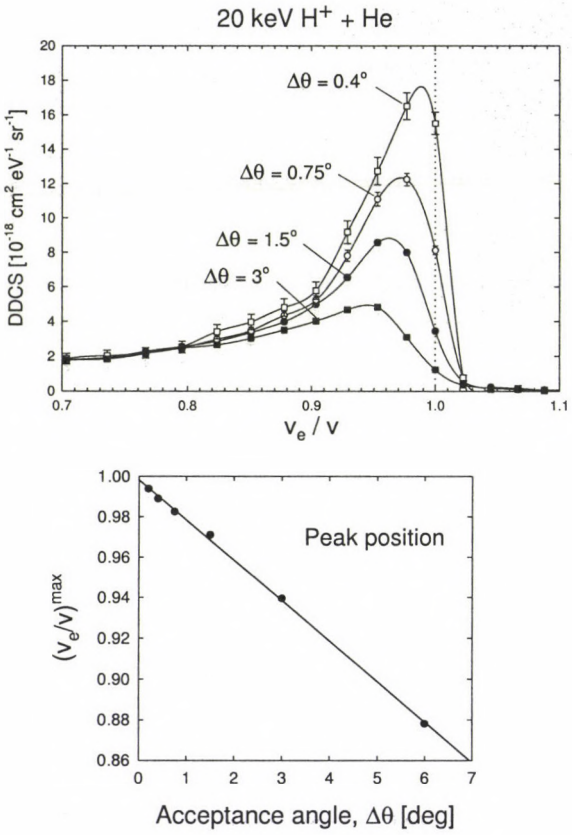

Figure 1. Upper part: Calculated double differential cross sections for the electron emission from 20 keV H^+ + He collisions at 0°. The curves are results of evaluations made for different acceptance angles of the electron detection (0.4°, 0.75°, 1.5° and 3°). Lower part: The position of the peak maximum as a function of the acceptance angle.

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3.10 Properties of the ECR plasma through X-ray images

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X-ray images of the plasma were recorded at the ECR ion source using a pinhole and a high resolution CCD camera [1]. The imaging system consisted of a 1.4M CCD camera and a 70 micrometer diameter X-ray pinhole. The 22 μm pixels permitted 0.1 mm spatial resolution. Operating with short exposure times, any individual pixel could be used as a single photon detector with an energy resolution of about 180 eV. This method has good spatial resolution as well as the capability of post-processed energy filtering of the images. Low and high charge state Ar, Xe and Fe plasmas were produced with simultaneous beam extraction. Full-size (Figure 1) and selected region images were recorded and analyzed [2].

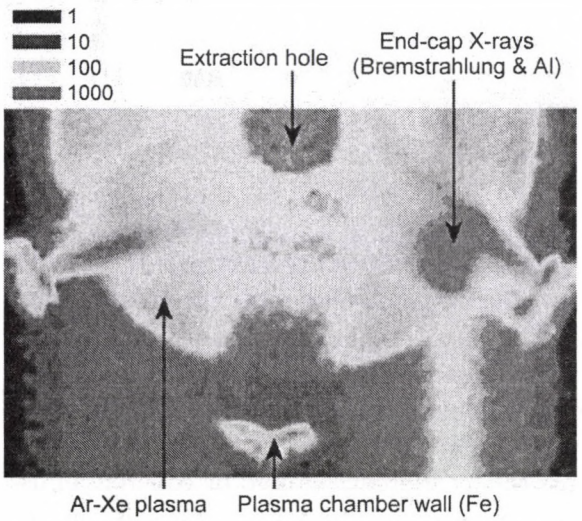

Figure 1. Typical X-ray picture of the ECR plasma.

In Figure 2 the energy spectrum of a full-size image Xe+Ar plasma image is shown. The inset pictures represent the (axially integrated) spatial location of the sources of the Kα (Ar) and Lα (Xe) characteristic radiation Also inset are Al and Fe sub-images due to Kα and bremsstrahlung radiation produced by energetic electrons lost in the metal walls of the plasma chamber. The radial distributions of the X-ray intensities along lines starting from the center toward different directions clearly show the strong inhomogenity of the plasma and also that it has much lower density around the axis of the system..

Images of selected plasma regions (extraction slit, magnet pole, magnet gap) gave a better understanding of the effect of important tuning parameters like bias disk voltage, gas mixing, microwave power, magnetic field strength etc. [2] These parameters are commonly used to produce highly charged plasmas and beams.

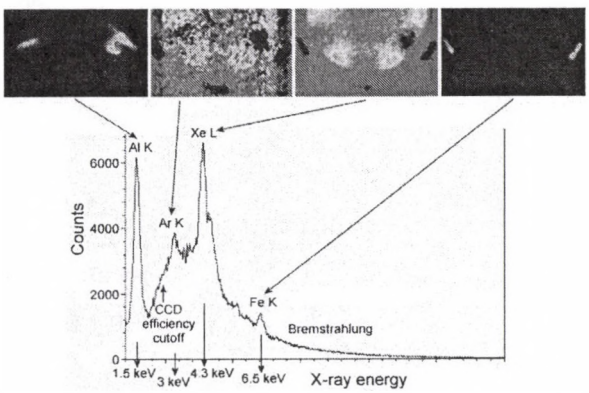

Figure 2. X-ray energy spectrum of a Xe-Ar mixture plasma. The small images show the locations of the sources of the X-rays.

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3.11 Interference Effects in Electron Emission from H_2 by 68 MeV/u Kr^{33+} Impact: Analogy to Young's two-slit experiment

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Studies of particle-induced ionization have devoted particular attention to the molecular target H , which is the simplest molecule composed of two atoms. While the overall ionization is well understood [1,2], little is known about phenomena associated with the indistinguishability of the atomic H centers. As outlined in Fig. 1, ionization of H_2 resembles Young's two-slit experiment where the atomic H centers (or slits) simultaneously emit radial waves. The coherent electron emission from the two centers may produce interference effects in the ionization spectra. Such interferences, which reveal the wave aspect of electrons, played an essential role in the early development of quantum mechanics.

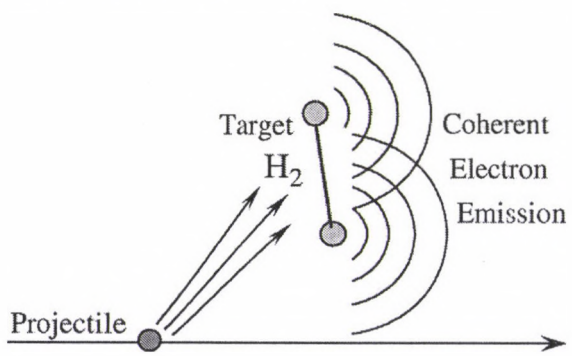

Figure 1. Electron emission from two identical centers smilar to Young's two-slit experiment

Recently, we found experimental evidence for interference effects in H_2 electron emission spectra induced by very fast projectiles [3]. In that work, hereafter referred to as (I), the analysis indicated that the use of a high projectile velocity is important because it enhances interference effects. The spectra obtained at forward angles (e.g., 30^o) exhibited an oscillatory structure in good agreement with model calculations. The experimental work has motivated several theoretical studies [4 - 6] which confirmed the existence of interferences in electron emission from H_2. In particular, Nagy et al. [5] shows explicitly that the frequency of the oscillation depends on the electron emission angle.

In the present work, we provided decisive experimental evidence for interference effects in electron emission from H_2 resulting from 68 MeV/u Kr^{33+} ion impact [7]. The experimental results clearly indicate a varying oscillation frequency of the interference pattern, in general agreement with the previous prediction [5] and calculations based on the Born approximation.

In accordance with the previous theoretical work [3 - 5] the cross section for electron emission from H_2 relevant for the present experiment is given by (atomic units are used throughout if not otherwise stated)

$$\frac{d\sigma_{H_2}}{d\Omega d\epsilon} = \int \frac{d\sigma_{2H}}{d\vec{q}d\Omega d\epsilon}\left[1 + \frac{sin(pd}{pd}\right] d^2q_\perp \qquad (3)$$

where the solid angle $d\Omega$ and the energy $d\epsilon$ refer to the outgoing electron. The cross section describes incoherent electron emission from the two independent H atoms (denoted by the label 2H), but mutually influencing their effective charges. The term in parenthesis represents the interference caused by coherent emission from the two centers where d is the internuclear distance of the H_2 molecule and $p = \left|\vec{k} - \vec{q}\right|$ is the difference between the electron momentum $\vec{k}$ and the momentum transfer in the collision $\vec{q}$.

The expression in Eq. (1) is obtained after averaging over the random orientation of the internuclear H_2 axis. The presence of the interference term shows that the averaging procedure preserves the oscillatory features of the electron emission spectra. Moreover, Eq. (1) must be integrated over the momentum transfer vector $\vec{q}_\perp$ perpendicular to the beam direction. This integration was carried out using

analytic cross sections $d\sigma_{2H}/d\vec{q}d\Omega d\epsilon$ for independent H atoms obtained from the Born approximation [1,2].

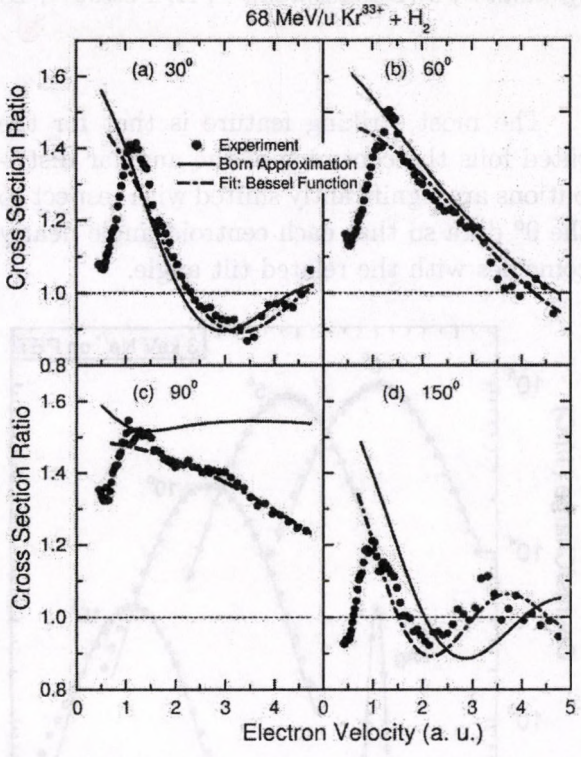

Figure 2. Ratios of experimental to theoretical CDW-EIS cross sections for electron emission in 68 MeV/u Kr^{33+} + H_2 collisions plotted as a function of the ejected electron velocity. From (a) to (d) the electron observation angles are varied as indicated. The solid lines represent Born calculations from Eq. (1) and the dashed-dot lines are obtained from fits using the analytic function of Eq. (2).

In Fig. 2 experimental and theoretical results are presented [14]. The experimental data are normalized to theoretical CDW-EIS [8] results for atomic hydrogen to remove the strongly varying factor $d\sigma_{2H}/d\Omega d\epsilon$. The adequately normalized results from the Born approximation are obtained using Eq. (1) and are plotted as solid lines in Fig. 2. Details are given in Ref. [7]. To obtain more information from experimental data we use the following fit formula

$$\left(\frac{d\sigma_{H_2}}{d\Omega d\epsilon}\right)_{nor} = F\left[1+\frac{sin(k\,c\,d)}{k\,c\,d}\right]+G \quad (4)$$

where F, G, and c are adjustable parameters. This formula was chosen in view of the theoretical prediction that the oscillation pattern is governed by a frequency parameter c, which in turn, depends on the observation angle as $c = cos\theta$ [5]. Since c may differ from the predicted value $cos\theta$, the quantity c was used as an adjustable parameter. The functions fitted to the experimental data are shown as dash-dotted lines in Fig. 2.

It is seen that the results from the Born approximation are in good agreement with experiment for 30° and 60°. Also, the Born results are found to agree well with the model calculations by Nagy et al. [5]. Accordingly the fit values of c agree well with $cos\theta$ for 30° and 60° confirming the prediction of an angular dependent oscillation frequency. However, discrepancies between the Born results and experiment occur for 90° and 150°. In particular, for 150°, the oscillation frequency is observed to be enhanced in comparison with the Born calculations. This finding, which is not fully understood at present, may indicate effects leading beyond the Born approximation [6].

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3.12 Guided transmission of Ne^{7+} ions through nanocapillaries in PET: dependence on the tilt angle

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During the past few years the creation of nanostructures in solids have received outstanding attention. A favourable tool for producing capillaries of high quality with respect of straightness and large aspect ratio is the use of ion tracks created by energetic projectiles in the solid [1]. By etching, the ion tracks can be transformed to mesoscopic capillaries whose dimensions range from a few nm to a few μm [2]. In our recent work we studied nanocapillaries of 100 nm diameter in highly insulating PET, which were produced by fast xenon ions with energies of several hundred MeV. [3,4]. The transmission of highly-charged ions through the capillaries was studied and an unexpected effect of ion guiding was discovered.

As a wall interaction strongly changes the ionic charge state [5], close contacts with the walls cannot occur. It was proposed that the incident ions deposit charges at the inner wall of the capillaries in a self-organizing process [3]. Hence, other ions are reflected far from the capillary walls so that charge exchange processes are inhibited. Thus, a considerable fraction of ions is guided through the capillary preserving its incident charge state. This mesoscopic *capillary guiding* is remarkable, since a large number of highly charged ions is transmitted through tiny tubes where a close contact with the walls seems to be inevitable.

In the present work, we investigate the transmission of Ne^{7+} ions through nanocapillaries at different incident angles. Angular distributions of Ne^{7+} ions are measured as they emerge from the capillaries. The guiding effect is demonstrated in Fig. 1, where the transmitted ion intensity is plotted as a function of the observation angle θ. The PET data are compared with results obtained with capillaries covered by Ag. The angular distributions for the Ne^{7+} ions transmitted through the PET capillaries are rather broad ($\approx$ 5° FWHM) regardless of the tilt angle (Fig. 1).

The most striking feature is that for the tilted foils the centroids of the angular distributions are significantly shifted with respect to the 0° data so that each centroid angle nearly coincides with the related tilt angle.

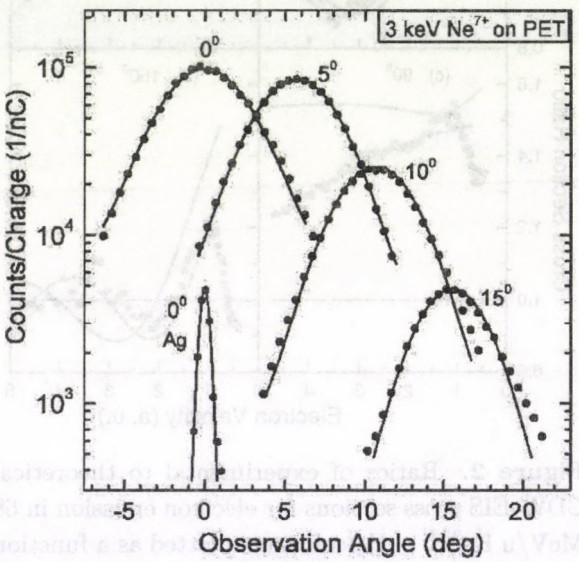

Figure 1. Angular distribution of Ne^{7+} ions transmitted through capillaries in PET foils. The foils were tilted by the angles indicated in the figure. The solid lines represent Gaussian functions fitted to the data. The distinct peak near 0° was obtained using capillaries covered with Ag.

The shifts of the angular distributions indicate that the direction of the incident Ne^{7+} ions is altered to a preferential direction parallel to the capillary axis, i.e., the ions appear to be guided through the capillary. It should be realized that with the capillary aspect ratio of 100, i.e., 10 μm length versus 0.1 μm diameter, the maximum angle is $\approx$ 0.5° for ions travelling on a straight line without touching the inner wall of the capillary (see also the Ag data). Consequently, Ne^{7+} ions transmitted through a foil tilted with angles > 1° have to interact at least once with the inner wall of the capillary. Nevertheless, as seen in Fig. 1, the

intensity loss is minor for Ne^{7+} ions transmitted through capillaries with 5° tilt angle and the Ne^{7+} intensity is still considerable at tilt angles as large as 15°. Obviously, for PET, a large fraction of the ions is guided through the capillary without changing their initial charge state. It is seen, however, that the transmission of the ions depends on the tilt angle.

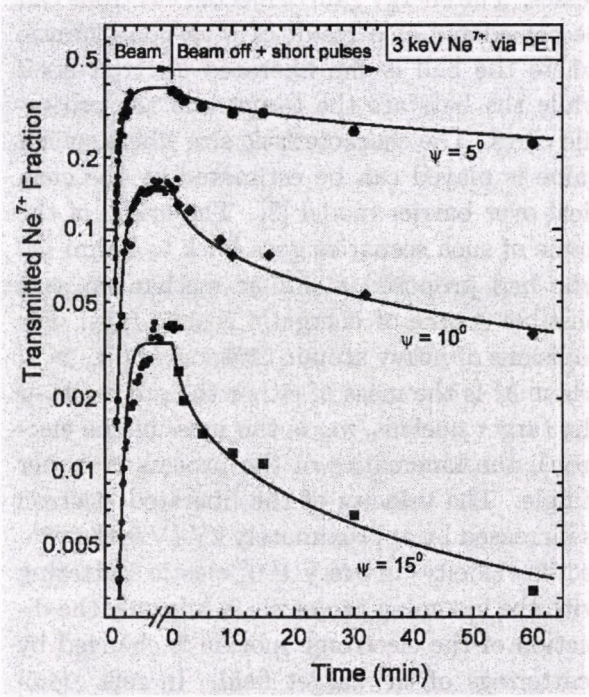

Figure 2. Time dependence of the transmitted Ne^{7+} intensity showing charging and discharging phenomena. A beam of $\approx$ 1 nA Ne^{7+} ions is directed onto the PET foil tilted at angles ψ = 5°, 10°, and 15°. The transmitted Ne^{7+} intensity increases nearly exponentially. After 10 min the beam is turned off. Short beam pulses probe the decrease of the transmission. The experimental results (points) are compared with model calculations (solid lines), see text.

Since the ion guiding is produced by charge-up effects, the ion transmission varies with time. In Fig. 2 the experimental results for the time evolution of the transmitted Ne^{7+} intensity, integrated over the emission angle α, are shown. When the beam is turned on, we observe the capillary charging with a time constant of τ_c. After 10 min the beam is turned off to verify the capillary discharging. It was found to take place with an effective time constant τ_d. This is done by probing the transmission by short beam pulses whose contributions to the capillary charging can be neglected.

To interpret the present results, we performed calculations using a non-linear model [4] with respect to the fraction of the transmitted ions, which is obtained as

$$f_p(t) = f_0\, e^{-\left(\frac{C_e}{q\,Q(t)}+b_s\right)E_p sin^2\psi}\,, \qquad (5)$$

where C_e is the capillary capacity near the entrance region, q is the projectile charge state, Q is the deposited charge, b_s is a constant, and $f_0 \approx 0.6$ is an empirical factor which takes into account the loss of ions transmitted through the capillary for zero tilt angle $\psi = 0$. More details are given in Ref. [4].

In Fig. 2 the results of the model calculations are given as solid lines. We note that the decay curves refer to the variation of the ion transmission rather than that of the deposited charge Q. Actually, for different tilt angles the model calculations yield about the same amount of charge finally deposited in the capillaries and, accordingly, the discharge time constants are nearly the same, too. However, for a given charge deposition the fraction of transmitted ions strongly depends on the tilt angle so that considerably different decay curves are obtained for the tilt angles used here.

The experiments have been performed at the ECR beamline of the ISL facility in Hahn-Meitner Institute Berlin. Work was supported in part by the Hungarian-German S&T Collaboration (D17/99).

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3.13 Ping-pong games in atomic scale

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Ionization is one of the fundamental phenomena studied in atomic collision physics. Differential spectra of the ejected electrons provide detailed information about the dynamics of the ionization process. Characteristic structures in these spectra can be associated with different collisions mechanisms. In energetic ion-atom collisions, most of the structures can be explained within the framework of first-order perturbation theories. However, large electron yields, compared to first order theoretical predictions, have often been observed in the high-energy part of the electron spectra in ion-atom, ion-molecule and ion-solid collisions. This relative enhancement of the high energy tail of the spectra of the emitted electrons can be rather strong especially in ion-solid collisions [1]. Such "hot" electrons may play significant role in many fields (astrophysics, ion-beam technologies) and hold also of considerable technological importance for the understanding of plasma physics or analytical methods.

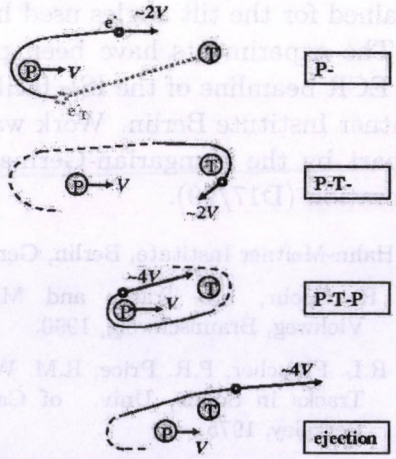

Figure 1. Classical "snapshots" of a P-T-P scattering sequence, starting with a binary collision between the projectile ion and the target electron.

In this work we focus on this high energy tail of the spectra in ion-atom collisions. Emphasis is given to the calculations. We demonstrate that these parts in the spectra can be associated with the multiple scattering processes. The energy gain of ejected electrons can be considered as a result of ping-pong games, where the ball is the liberated electron itself while the bats are the target and the projectile cores. The characteristic size where such a game is played can be estimated by the classical over barrier model [2]. The origin of the name of such scenarios goes back to Fermi [3], who had proposed a similar mechanism as a possible source of energetic cosmic rays. For collisions of heavy atomic centers ($M/m_e \gg 1$, where M is the mass of either the projectile or the target nucleus, m_e is the mass of the electron), the kinematics of the process is rather simple. The velocity of the liberated electron is increased by approximately 2V (V is the projectile velocity) in every 180° elastic scattering with the incoming projectile, while only the direction of the electronic motion is changed by scatterings of the target field. In refs. [4,5] we introduced the shorthand P and T to denote the electron-projectile and electron-target scatterings, respectively. If the first P scattering of the electron e.g. is followed by a second scattering on the target field, it is called a P-T process. Notations like P-T-P or T-P-T-P refers to longer sequences.

In ion-atom collisions, higher orders of multiple electron scattering can be treated practically *only* by applying a non-perturbative model. Therefore we performed a three-body classical trajectory Monte Carlo (CTMC) calculations. In the present CTMC approach, Newton's classical nonrelativistic equations of motions for a three-body system are solved [6]. For description of the interactions among the screened ionic cores and the active electron an analitic model potential is used derived from Hartree-Fock calculations. It has been developed by Green and coworkers [7].

At first we applied our CTMC method at the impact of intermediate velocity C^+ projec-

tile ions on inert gases. The predicted CTMC results were in good agreement with the experimental data [4,5]. Moreover, by the help of the analysis of the longitudinal momentum transfer values to the target and projectile cores during the collision, the P-T-P and P-T-P-T multiple scattering contributions were clearly separated and identified [5].

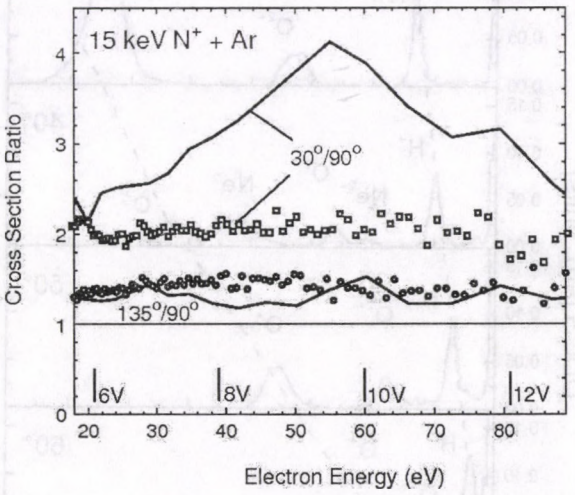

Figure 2. Ratios of the double differential cross sections for electron emission in 15 keV N^+ + Ar collisions. Forward and backward spectra are diveded by the 90^o reference data. Symbols: experimental data [8], solid lines: CTMC calculations. Multiples of the projectile velocity are indicated.

Along this line we extended both our measurements and calculations to the lower projectile energies. We performed a set of new experiments from low to intermediate projectile velocities. Experiments for 10 and 15 keV/u N^+ + Ar collisions have been performed at the ISL beamline of Hahn-Meitner Institute, Berlin [8]. In the 50-100 keV/u impact energy range, we studied many collision systems at the beamline of the 5 MV Van de Graaff accelerator in ATOMKI, Debrecen, including $N^+ + N_2$, Ne, Ar, $N_2^+ + N_2$, Ne, Ar.

The comparison of the results of the above, and also earlier [9], experimental studies with our CTMC calculations provided a rather good general agreement. As an example, we show measured and calculated differential electron emission cross section ratios for slow collisions of N^+ ions with Ar atoms in Fig. 2. Both the forward (30^o) and the backward 135^o) emitted spectra are divided by the 90^o data to observe anisotropies in the angular distribution. Such anisotropy patterns are characteristic for multiple scattering processes. It is clearly seen that CTMC accounts both the observed forward-backward enhancement of the electron emission, and the asymmetry with a larger yield into the forward direction. Moreover, CTMC results provide a qualitative agrement for backward electron emission angles. At the same time, CTMC overestimates the measured anisotropy in the forward direction.

We note that the displayed energy region belongs to 5-12-fold multiple scattering of the emitted electrons, as indicated in the figure. Indeed, the dominance of such events has been confirmed by the individual analysis of the CTMC trajectories. It is worth noting that no electron emission is predicted in this energy region by first order perturbation theories.

A preliminary analysis of the CTMC events for many collision systems indicates the presence of rather long (6-14-fold) Fermi-shuttle type scattering sequences in the 1-50 keV/u impact energy region. In some collision systems, such long games seem to contribute to the ionization process significantly. A detailed evaluation of the data is in progress.

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3.14 Fragmentation of H_2O Molecules Following the Interaction with Slow, Highly Charged Ne Ions

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The fragmentation of molecules induced by the interaction of highly charged ions (HCI) has been investigated intensively in the past decade. Most of these studies have been performed with diatomic molecules, especially with the simplest molecules H_2 and D_2. In addition to Coulomb explosion (CE), the energy of the H^+ fragments is influenced by the collisional momentum transfer to the molecule, as well as by the post-collision field of the scattered slow highly charged ion [1,2]. In this work, we investigate the molecular fragmentation of H_2O molecules, whose applications are numerous. These experiments were performed using slow, highly charged Neq+ ions produced by the 14.5-GHz Electron Cyclotron Resonance (ECR) ion source facility at the Ionenstrahllabor (ISL) [3]. The energy of the projectile was varied from 2 to 90 keV, while its charge state ranged from 1 up to 9. The experimental chamber with a base pressure below 2 x 10^{-7} mbar contains an electrostatic parallel-plate spectrometer, which can be rotated from 18^o to 135^o with respect to the incident ion beam direction.

Fig. 1 presents the energy distributions of ions produced in collisions of 5 keV Ne^+ ions with H_2O molecules. The observation angle was varied from 30^o to 60^o in steps of 10^o. Two groups of peaks are energetically separated: a low energy group (below 100 eV) which does not show a significant energy shift, and a group of peaks whose positions are angular dependent. In Fig.1, the peaks with energies above 100 eV can be associated to binary collisions between the projectile and a single target atom. The scattering of Ne^{q+} projectiles up to 40° is also a signature of collisions at small impact parameters with the oxygen atoms. On the contrary, the presence of slow species (energies ¡ 100 eV) can be explained by means of a CE model. In most of cases, these slow fragments are identified as H^+ ions.

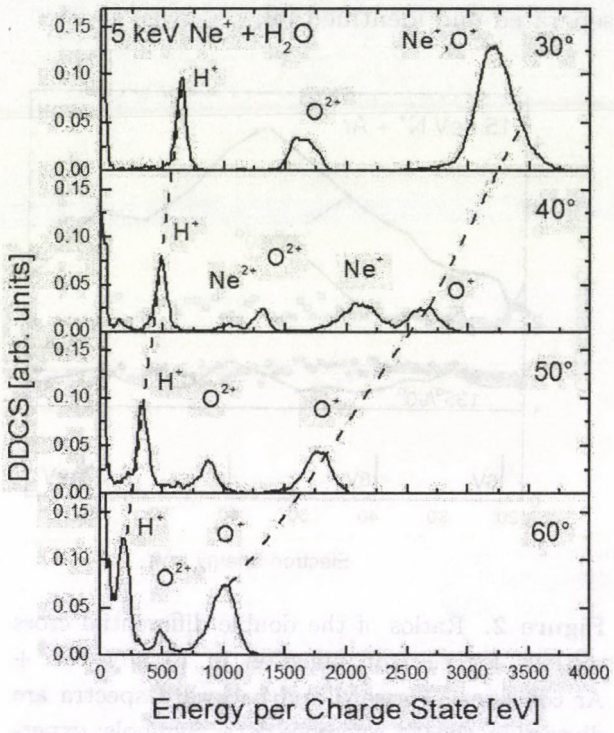

Figure 1. Energy spectra of ions from collisions of 5 keV Ne^+ with H_2O, measured at the observation angles 30^o, 40^o, 50^o and 60^o. The lines are drawn to guide the eye.

We have also remarked that increasing the charge state of the projectile, the energy difference of the peak positions at the largest forward and backward observation angle increases. Furthermore, the experiment shows that the angular dependence is more pronounced for decreasing energy of the projectile. Therefore, it is attributed to the influence of the post-collision field of the scattered ion. The role of the post-collision interaction for lighter projectiles has previously been revealed [4]. In the present case, fragment ions emitted in forward direction are decelerated, while those emitted in backward direction are accelerated. The deceleration or acceleration is stronger if the interaction time and/or the

charge of the projectile increases.

In Fig. 2 (a) we show the projectile charge state dependence of the differential cross sections for fragmentation of H_2O. The energy of Ne^{q+} (q=3, 5, 7 and 9) projectiles is 21 keV, and the detection angle is 25^o. The lines are drawn to guide the eye. The peak labeled Oxygen is due to O^{Q+} ions, whereas the peak Q=0 corresponds to H^+ ions originating from the $H^+ + H^+ + O^0$ fragmentation. The differential cross sections for the production of H^+ ions, following fragmentation into $H^+ + H^+ + O^{Q+}$ and/or $H^+ + H^0 + O^{Q+}$, are labeled Q=1, 2 and 3 in Fig. 2 (b).

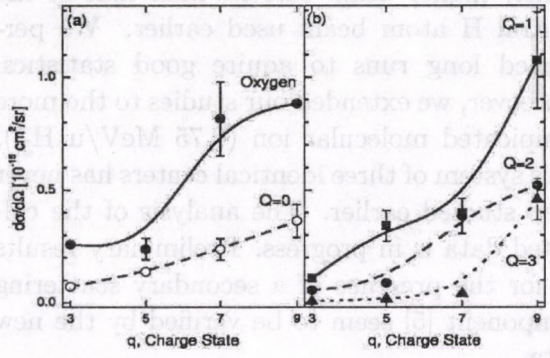

Figure 2. Differential cross sections for fragmentation of H_2O molecules by 21 keV Ne^{q+} at 25^o as a function of charge state of the projectile.

Fig. 2 shows a strong monotonic increase of the differential cross section for fragmentation with increasing projectile charge state, which is especially pronounced for the peaks labeled Oxygen and Q=0, as well as for peak Q=1. In particular, the intensity of peak Q=3 (explosion which produces oxygen ions with charge state Q=3) increases strongly when the incident charge of the projectile increases from q=7 to q=9, while its intensity shows only a slight increase in the range from q=3 to q=7. This indicates that an open projectile K-shell significantly influences the multiple electron capture. Here we did not plot data where the charge state Q of the oxygen fragments exceeds 3. Fragments from this channel are present for Ne^{q+} projectiles and this a signature for the capture of 4 or 5 electrons.

For the projectiles with charge states q=3-7 prediction of the COB model agrees well with measured cross sections. In fact, double-electron capture calculated using the extended COB model for projectile with charge state q=3 nearly coincides with the measured value, while for higher charge states of the projectile (q=5,7) better agreement of the model with the experiment is achieved when taking the sum of double and triple electron capture.

In conclusion, two regions, due to the binary collisions and Coulomb explosion, are separated in the energy spectra. Furthermore, a strong charge-state dependence was found. The CE model indicates that for low projectile charge states fragmentation to two charged particles and one neutral particle is dominant, while for high charge states of the neon ions, fragmentation to three charged particles is more probable.

The experiments have been performed at the ECR beamline of the ISL facility in Hahn-Meitner Institute Berlin. Work was supported in part by the Hungarian-German S&T Collaboration (D17/99).

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3.15 Collisions of H_2^+ and H_3^+ molecule ions with He and Ar targets: Search for interference effects in the molecular electron emission

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At the end of 2002, we started a systematic search for interference effects in electron emission from molecular ions. The study has been motivated by recent results in the ionization of the neutral hydrogen H_2. The two atomic centers in this simple molecule can not be distinguished, therefore their electron emission contributions may add coherently. First experimental evidence for such interference effects has been found in the electron emission spectra in collisions of very fast and highly charged (60 MeV/u $Kr34^+$) projectiles with H_2 molecules [1]. In subsequent theoretical studies [2,3], the basic features have been analyzed. In a recent experimental study, many of their prediction has been verified [4,5].

Since the simplest molecular system, is not H_2 with two electrons, but the H_2^+ molecular ion, we turned to study the ionization of the latter structure. At first sight, the symmetries of the H_2 molecule are also present in this one-electron system, but electron-electron interactions do not alter the picture. In Ref. [2], interference in the ionization of the neutral H_2 molecule has been treated within a two-effective center approximation, which partially accounted the correlation between the emitted and bound electrons. It is not clear, whether interference is only due to symmetry properties, or electron correlation in H_2 also plays a significant role.

In the beginning phase of the present work, we studied electron emission from H_2^+ molecule ions colliding with He and Ar targets (the inverse collision system). A beam of 1.5 MeV/u H_2^+ ions was directed to gas jet targets, and electron spectra were collected in the entire 0-180^o angular range. The experiments have been performed at the beamline of a 5 MV Van de Graaff accelerator in ATOMKI, Debrecen. For reference purposes, we also collected spectra in collisions of 1.5 MeV H^0 atoms with the same targets. The statistics of the aquired data, however was not enough to perform a conclusive analysis. Preliminary results have been published at conferences [5].

In the present stage of the work we extended our experiments for slower collisions (0.75 MeV/u H_2^+ + He, Ar). For reference purposes, we used the one-electron atomic ion (0.75 MeV/u He^+) projectile, whith a significantly higher beam current than that of the neutral H atom beam used earlier. We performed long runs to aquire good statistics. Moreover, we extended our studies to the more compicated molecular ion (0.75 MeV/u H_3^+). This system of three identical centers has never been studied earlier. The analysis of the collected data is in progress. Preliminary results [6] for the presence of a secondary scattering component [5] seem to be verified by the new data.

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4.1 The effect of iron substitution in $La_{0.8}Sr_{0.2}Fe_{0.05}Co_{0.95}O_{3-\delta}$ and $Eu_{0.8}Sr_{0.2}Fe_xCo_{1-x}O_{3-\delta}$ $(0 \leq x \leq 0.3)$ perovskites

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The $La_{0.8}Sr_{0.2}Fe_{0.05}Co_{0.95}O_{3-\delta}$ and $Eu_{0.8}Sr_{0.2}Fe_xCo_{1-x}O_{3-\delta}$ $(0 \leq x \leq 0.3)$ perovskites were investigated by ^{57}Fe and ^{151}Eu transmission Mössbauer spectroscopy, ^{57}Co emission Mössbauer spectroscopy, as well as by AC and DC magnetic susceptibility measurements.

At room temperature the oxidation state of europium in $Eu_{0.8}Sr_{0.2}Fe_xCo_{1-x}O_{3-\delta}$ was found to be Eu^{3+} without any hint for the possible existence of Eu^{2+}. Iron substitution up to x = 0.3 was found to have little if any effect on the local electronic state of europium, showing that independent of the stoichiometry of the transition metal layer, oxygen coordination and the electronic state of Eu remains unchanged. Temperature dependence of the ^{57}Fe Mössbauer isomer shift, quadrupole splitting, line broadening and relative spectral area was determined in a detailed manner in order to establish possible correlation between the local state of iron and the bulk magnetic properties in $La_{0.8}Sr_{0.2}Fe_{0.05}Co_{0.95}O_{3-\delta}$. We have found that around a transition temperature at ($\cong$ 150 K) the ^{57}Fe Mössbauer parameters change anomalously, indicating a change in the vibrational state of the iron at this temperature. This variation is reflected as well by the onset of dissipation in the AC susceptibility. We argue that this change may be a consequence of the formation of Co^{4+} rich superparamagnetic clusters and the connected electron localization in the paramagnetic matrix which segregation is promoted by the iron doping.

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4.2 Solid-state reaction in Ti/Ni thin film system on silicon single crystal

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Low electrical resistivity has been a major consideration in the selection of thin film silicide as ohmic contacts or gates in microelectronics devices [1]. Beside $TiSi_2$ and $CoSi_2$, the only other silicide which has resistivity near 10 $\mu\Omega$·cm is the nickel mono-silicide NiSi [2]. However, NiSi is known to transform to $NiSi_2$ near 1020 K in the binary system of Ni on Si [3]. How to stabilize the NiSi to higher temperature has been a subject of wide interest. In the given work solid-state reaction in thin-film system 200 nm Ti/200 nm Ni are investigated. The purpose of work consist in research of influence of a superficial layer of the Ti on processes of silicide formation, in particular, on increase thermal stability of NiSi.

The layered Ti/Ni films were deposited on (001) Si wafers by electron beam deposition. Samples were thermally treated in temperature range from 470 to 1270 K . For phase identification in local regions and for microstructure characterization upon annealing, selected area diffraction, TEM and XTEM were performed.

During experiments it was established, that after annealing of initial sample at temperature 473 K there is a formation of the flat amorphous particles with the size 0.2 nm and which are not having a precise facet. At rise in annealing temperature up to 700 K they being to crystallize in particles of the rectangular form with the precise facet and the size 400 nm, determined as mono-silicide NiSi phase. Further annealing of samples at 870 K for 1 hour dose not change qualitatively the phase structure. Due to further mutual interdiffusion and reaction, the amount of nickel monosilicide was increased. After annealing at 970 K for 1 hour the X-ray diffraction data indicated the formation of Ti_5Si_3 alongside with NiSi and Ni_3Ti. It is known that the monosilicide NiSi formed in the binary Ni/Si film system is stable up to temperature of 1020 K. To study the thermal stability of NiSi in our sample, we have annealed them at 870 K for 8 hours. From data of X-ray diffraction, we found that the annealing at 870 K did not cause essential changes of their phase structure. Intensive reflection of the phase of Ni_3Ti, Ni_2Si, NiSi and pure Ti are identified. The samples showed a sharp reduction of electrical resistance, which can be explained by the formation of NiSi. After annealing at 1070 K for 1 to 2 hours no change of electrical resistance of the sample was observed. It confirms the thermal stability of NiSi at 1070 K. Only when the annealing temperature was increased to 1270 K, the $NiSi_2$ form and the formation accompanied by a slight increase of electrical resistance. The improved thermal stability of NiSi in the annealed 200 nm Ti/200 nm Ni/(001) Si film system, in comparison with the NiSi in binary Ni/Si system, is most likely due to the presence of Ti in the grain boundaries of NiSi and/or the formation of the intermetallic Ni_3Ti. These data testify that the thermal stability of NiSi phase formed in the Ti/Ni/Si is better than the NiSi formed in the binary system of Ni/Si. We assume that atoms of Ti in the grain boundaries of NiSi and/or the low interfacial energy between NiSi and Ni_3Ti have hindered the nucleation and growth of $NiSi_2$.

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4.3 Degradation of Ag/Si multilayers during heat treatments

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The ability to create interfaces with well-defined structures is technologically important in synthesizing interfacial materials with unique optical, electronic, catalytic, magnetic and mechanical properties. On the other hand, the understanding of growth processes at surfaces is important for scientific reasons as well. During recent years considerable experimental and theoretical efforts have been focused on investigation of metal/amorphous Si films that are miscible (W/Si, Mo/Si, Co/Si) [1]. But only a few reports about the metal/amorphous Si multilayers with practically no miscibility [2] have been published and our knowledge about their thermal stability or micro structural development is very little so far. Zhao et al. [2] have studied the thermal evolution of Ag/a-Si multilayers and found that the main diffusion mechanism was the diffusion of silicon atoms along the silver grain boundaries with a surprisingly small activation energy (0.24 eV) between 373 and 523 K, the silicon sublayers became thinner and silver sub-layers transformed into discontinuous ones.

In our experimental studies the microstructural development during thermal annealing of Ag/a-Si multilayers were measured by X-ray diffraction (XRD) and transmission electron microscopy (TEM). The results show that our samples are much more stable than those investigated by Zhao et. al., i.e. any changes of the multilayer structure occur at higher temperatures. For example, the formation of granular structure took place at temperatures about 200 K higher than reported in. It should be noted that, in their samples, the Ag/Si ratio was larger (as can be seen, in their TEM images) and their Ag/a-Si multilayers were prepared by ion beam sputtering deposition.

Plan-view TEM observations on a-Si4.5nm/Ag4.5nm/a-Si4.5nm trilayers showed that after heat treatment at 723 K for 1 h in high purity Ar, the Ag layers agglomerate. The separated Ag particles have diameters ranging from 10 to 80 nm (the mean diameter is about 50 nm). This degradation process was much faster than in the multilayer system for the same layer thickness. This fast granulation can be caused by the mechanical stresses (as-deposited or induced by the diffusion process).

Furthermore, on the basis of the details of structural changes observed we emphasize that estimation of any diffusion coefficient from the usually applied decay law, according to which the $\ln(I/I_o)$ versus time (t) function proportional to D/λ^2, is very questionable [3]. Indeed this relation can be applied only if the process is a gradual smoothening of the interfaces (with a unique diffusion mechanism and concentration independent coefficient [3]), which results in a formation of solid solution. Thus it would lead to unrealistic results if applied to the degradation process observed by us, and characterized by grain-boundary pinhole formation and granulation of the silver layer.

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4.4 Effect of hydrostatic pressure on crystallization and decomposition in amorphous Si/SiSb/Si system

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Si-based amorphous alloys are receiving growing attention and they have extensively studied and utilized because of their electronic and optical properties. Investigations concern the electronic and optical properties of the alloys. However, the subject related to the amorphous-crystalline transition, segregation, decomposition and diffusion still has numerous unanswered question. The thermal stability of Si-Sb amorphous alloys was investigated in Refs. [1,2]. According to Ref. [1], the crystallization temperature decreases monotonically from 1073 K (pure Si) to 623 K for 50 at.% Sb/Si amorphous alloy. The crystallization products were found to be nano-crystalline Si, Si-Sb mixture or Sb, depending on the initial composition of the alloy.

Amorphous Si/Sb monolayer-, Si/SiSb/Si trilayer- and Si/SiSb multilayer-films were deposited by alternate sputtering of pure elements Si and Sb in a DC magnetron sputtering onto Si substrate. Annealing treatments were performed at temperature of 883 K in vacuum ($p \approx 5 \cdot 10^{-7}$ mbar) or in Ar atmosphere at 1 bar, 100 bar and 4.7 kbar pressure for 2 hours. The samples before and after annealing was investigated by transmission electron microscopy (TEM) and Rutherford backscattering spectrometry (RBS).

Originally our aim was to investigate the role of the interface in the intermixing in mono- tri- and multi-layer Si/SiSb system. Instead of formation of a homogenous crystalline Si, SiSb mixture we realize a characteristic pattern formation in the Sb containing layer. The distribution of the Sb-rich regions was not random, but the density of these regions was higher at the amorphous-crystalline interface and in the middle of the Sb containing layer, forming a striped morphology. Furthermore, during annealing of Si/SiSb amorphous samples under hydrostatic pressure a crystallization of the amorphous SiSb layer was observed, while the pure Si layers remained amorphous. The transformation at the given temperature strongly dependents on the initial Sb concentration of the SiSb layers and the applied hydrostatic pressure. In the case of the trilayer film, the final morphological patterns with three stripes parallel to the substrate surface refers to a spinodal-like decomposition. This striped morphology can only observed in trilayer-type samples. Neither multilayer nor monoleyer arrangement, independently of the Sb concentration, show such type of behavior. TEM and RBS studies revealed that the decomposition of the SbSi layers occurs but the Sb-rich region show random distribution, so the striped morphology cannot be seen.

On the other hand, the concentration distribution and the number of maxima does not change when the thickness of the middle SiSb layer was increased. This experimental finding does not support the spinodal character of the decomposition. The observed phenomena and the striped morphology of the final state can be explained by segregation, diffusion and crystallization. Because of size effect, a rather strong tendency for segregation of Sb can be expected. Diffusion and segregation may occur in the amorphous state, which will be accelerated by the formation of grain boundaries. The enrichment of Sb along the crystalline-amorphous interface could be explained by segregation, but the explanation of the concentration maximum (stripe) in the middle of SiSb layer needs more sophisticated consideration.

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4.5 Determination of the alloying elements in Hungarian beaker metallurgy by XRF analysis

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The so-called Bell Beaker culture spread into Europe, especially the western areas, in the first half of the 3rd millennium BC. A group of this culture came in to the Carpathian Basin along the Danube. Burials and increasingly large numbers of settlements have come to light in the area around Budapest. The metal artefacts of the Bell-beaker culture in Hungary have not been subjected to archaeometallurgical examinations yet. Thus detailed study of this baker metal technology has been started on some metal objects found recently in an excavation.

For non-destructive elemental analysis of the artefacts both the energy dispersive X-ray fluorescence (XRF) spectrometry and the proton induced X-ray emission (PIXE) method with external proton beam was possible. From comparative measurements using standard set up and measuring time for each technique it was concluded that XRF, which in addition gave an average of the elemental concentration on a few cm^2 surface, is more sensitive for the heavy trace elements in the samples than PIXE, thus for further analysis XRF was chosen.

The radioisotope excited XRF measurements were performed using the 59.5 keV gamma-line of the annular ^{241}Am source. The X-ray spectra were collected by a Si(Li) detector with an energy resolution of 190 eV for Mn-K_α X-rays. The typical measuring time was 50000 s. The characteristic X-ray spectra obtained from the samples were evaluated by non-linear least-squares fitting, using the Axil X-ray analysis software. *Table 1* (see next page) presents the results of the quantitative analysis.

The main purpose of the analyses was to examine if there existed a similarity in the composition of the finds. For that purpose the similarity dendrogram of the object was produced by mathematical statistical method (Fig. 1).

The analytical results were separated into four groups: *Group 1:* AL330, AL420, AL784, AL343; *Group 2:* BM68113, BM68115, BM145, SV7, SV80; *Group 3:* CR331; *Group 4:* 36obj, AL68.

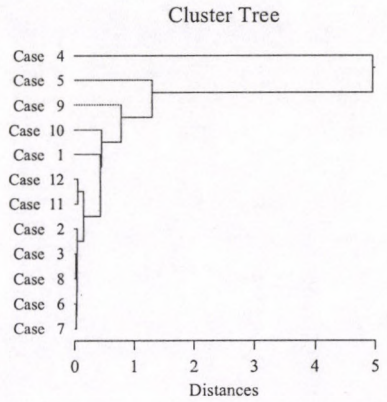

Figure 1. Comparison dendrograph of components of the 12 artifacts (Case N° identified in Table 1)

The discussion of the analytical results, including the detailed description of the archaeological finds, have been presented on the Int. Conf. on Archaeometalurgy in Europe, 24-26 Sept., 2003, Milan, Italy.

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Table 1 . Data on the contents of Szigetszentmiklós, Albertfalva, Békásmegyer and Csepel artifacts by XRF analysis (% of weight).

N°	Identity	Object	Site	Cu	Ag	Sn	Sb	Pb	As
4	36obj	Roll-headed pin	Albertfalva	85.312	1.923	6.783	1.264	0.348	4.37
5	AL68	Awl	Albertfalva	95.918	0.192	3.015	0.021	0.544	0.31
9	CR331	Dagger	Csepel	97.192	2.260	0.037	0.319	0.192	nd
10	BM145	Dagger	Békásmegyer	98.167	0.290	0.837	0.470	0.236	nd
1	SV80	Dagger	Szigetszentmiklós	98.576	0.933	0.066	0.178	0.246	nd
12	BM68113	Awl	Békásmegyer	99.382	0.188	0.082	0.021	0.327	nd
11	BM68115	Dagger	Békásmegyer	99.407	0.260	0.032	0.061	0.240	nd
2	SV7	Dagger	Szigetszentmiklós	99.717	0.112	0.043	0.015	0.113	nd
3	AL343	Pinhead	Albertfalva	99.806	0.050	0.034	0.004	0.107	nd
8	AL784	Frag. object	Albertfalva	99.839	0.003	0.038	0.002	0.118	nd
6	AL330	Pin	Albertfalva	99.921	0.005	0.010	0.002	0.062	nd
7	AL420	Ring	Albertfalva	99.959	0.004	0.024	nd	0.013	nd

4.6 Surface analytical study of ZnO, CuO and Al_2O_3 using a special XPS-XAES x-ray source [1]

J. Tóth, D. Varga, L. Kövér, I. Cserny

In this study a combination of a home built conventional X-ray Photoelectron Spectroscopic (XPS) X-ray source with a specially designed "hard" X-ray source for the excitation of Auger lines of the few keV energy range is presented including the main characteristics of the two X-ray tubes.

The home built XPS-XAES-REELS (XAES: X-ray Excited Auger Electron Spectroscopic; REELS: Reflection Electron Energy Loss Spectroscopic) instrument (ESA-31) [1] equipped with the mentioned special X-ray sources has been used for studying different materials: semiconductors, 3d elements, etc.

By the help of the ESA-31 XPS electron spectrometer [1,2] with different X-ray excitation sources (anodes: Al, Ag, Mo, Cu), the PAX (Photoionization by X-ray Absorption) method, as a high energy resolution X-ray spectroscopic method, the natural line widths of atomic inner shells [3,4] were studied.

The methods for energy calibration of the electron spectrometers in the high-energy range using relatively high energy X-ray excited photoelectron lines [5] and Auger lines [6] are also discussed.

The "XS by XPS" method was used for the determination of intensity ratios of different x-ray lines providing important information for quantitative analysis. Different converters (samples) were used for this purpose: Al2O3, ZnO and CuO in powder form pressed into a pellet and stuck onto a double-sided sticky tape.

For measurements of detection efficiency of the spectrometer the REELS spectra [7,8] of the Ni specimen was used.

The chemical state and composition of the materials ZnO, CuO, Al2O3 was verified using conventional Al K excited photoelectron spectroscopy.

Assuming that the stoichiometry, the photoionization cross sections and the efficiency correction factors are known, the energy dependence of the ratios of the respective inelastic mean free paths can be determined in the high energy range using various energy (e.g. Mo) X-rays for excitation. The energy dependence of the IMFP determined by EPES method [9,10,11,12,13,14] and the present XPS method are compared and discussed.

Experimental methods used

In the present study surface electron spectroscopic methods of XPS (X-ray Photoelectron Spectroscopy, XAES (X-ray excited Auger Electron Spectroscopy, REELS (Reflection Electron Energy Loss Spectroscopy, EPES (Elastic Peak Electron Spectroscopy) were used.

Acknowledgements

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5.1 The Origin and Mixing of Water in Catchment Area of Main-channel Lónyai

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The goal of the national project entitled Hydroecology of River Tisza and Upper Tisza-Region (NKFP-3B/0019/2002) is to provide scientific foundation of the hydroecological state assessing, monitoring and databank organising program of River Tisza and Upper Tisza-Region supplementing with pilot-projects of practical realisation. In the first phase of this project our task was the investigation of the origin and mixing of water in the catchment area of Main-channel Lónyai. For this aim stable isotope ratios (δD, δ^{18}O, δ^{15}N, δ^{34}S, δ^{13}C) were measured in water and sediment samples taken from the catchment area of Main-channel Lónyai. Three samples were taken from the main channel, and two side channels were represented by 2-2 samples.

Naturally occurring stable and radioactive isotopes of the elements of the water molecule (water isotopes) and the compounds dissolved in water have increasingly been used to study hydrological, hydrochemical and environmental processes in rivers and their catchment areas. The most frequently used isotopes and their applications are the following:

Isotopes	Application
^{2}H/^{1}H	Water balance & dynamics in river catchments, basins and estuaries; surface-groundwater interrelation
^{13}C/^{12}C	Riverine carbon cycle; weathering processes; pollution; biological processes
^{15}N/^{14}N	Pollution; biological processes
^{18}O/^{16}O	Water balance & dynamics in river catchments, basins and estuaries; surface-groundwater interrelation
^{34}S/^{32}S	Pollution; salt depositional processes

Special emphasis was placed to the water isotopes tritium and ^{18}O because of their specific potential in addressing water balance, dynamics and interrelationships between surface and groundwater in river basins and catchment areas.

The most negative δ^{18}O values were measured near the sources of the two side channels: both of them had δ^{18}O = -9.7‰. This value is characteristic for the deep groundwater in Nyírség [1-2]. In a distance of several kilometers from the sources the water in both of the channels had less negative delta values than at their origin. It means that the channels were fed by direct overland runoff during their route and no subsurface water was added.

Main-channel Lónyai carries large amount of communal wastewater to River Tisza. The measured delta-values showed a large inflow from subsurface water body between Kék and Ibrány. The δ^{15}N value of the dissolved ammonium measured at Ibrány indicated presence of manure, so the water came from communal wastewater. The δ^{18}O value of the water sample taken near the channel-mouth showed that the water was mainly of subsurface origin with a small contribution of overland runoff, and the effect of evaporation was insignificant. The tritium content of this water was $\sim$ 0.1 Bq/l. The annual average of tritium concentration in precipitation in Debrecen [3], as well as the tritium concentration measured in River Tisza at Tiszabecs is about ten times higher: $\sim$ 1 Bq/l. It supports the conclusion drawn from the stable isotope results: the water used for communal purposes originates from old, deep subsurface water body.

C, O and S isotope ratios measured in the sediment samples were similar to each other, mixing of organic and inorganic compounds could be observed.

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5.2 Investigation of headspace gas of low and intermediate level radioactive waste containers (Theses of the PhD dissertation)

M. Molnár

I developed the first reliable gas-sampling devices and sample pre-treatment methods for the case of investigated real L/ILW waste packages. Using these devices and methods I carried out successfully repeated sampling and measurements of twenty-five L/ILW drums of Paks NPP for wide range storage period. For the first time I carried out post closure headspace gas sampling and analysis from two near surface L/ILW vaults of the CRWTDF of Hungary (closed in 1972).

Using a special calibration method a quadrupole mass spectrometer was applied for the qualitative and quantitative composition variation measurements of headspace gas samples from real L/ILW drums and vaults. Only small carbon-dioxide surplus was measured in the headspace gas of the investigated vaults. The detected generated gas components in the investigated drums were: hydrogen, methane and carbon-dioxide, depending on the type of the waste. Hydrogen production was typical of compacted waste drums with 1-10% H_2 concentrations of theirs headspace gas. Methane production was typical of sludge waste drums. After a few weeks storage the CH_4 always becomes the main component of their headspace gas. Carbon-dioxide gas production with variable rates is a general phenomenon in waste drums. The obtained results represent the input data for further gas generation models.

I developed a sample pre-treatment method and device for isotope-analytical measurements of headspace gas samples. This device is suitable for converting water vapor, hydrogen, methane and carbon-dioxide fractions of gas samples into proper chemical forms for isotope analytical measurements, like ^3H and ^{14}C activity or $\delta^{13}C$ and $\delta^{18}O$ stable isotope ratio measurements.

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. My results show that the typical gas generation rates (v_{Gas}) were v_{H_2}: $\sim$ 0.1-10 STD cm^3/day, v_{CH_4}: $\sim$ 10-1000 STD cm^3/day and v_{CO_2}: $\sim$ 1-100 STD cm^3/day, depended on the type of the waste.

On the basis of δ^3He, $\delta^{13}C$ and $\delta^{18}O$ stable isotope ratio measurements from the headspace gas of L/ILW packages I ascertained:

- presence of α-emitter in the L/ILW,
- presence of large amount of ^3H in the L/ILW,
- out crowding rate of original headspace gas (air),
- the possible sources of CO_2 and CH_4 generation.

I measured the ^3H and ^{14}C activity concentrations in hydrogen, water vapor, methane and carbon-dioxide from the headspace gas of L/ILW packages. The tritium activity concentrations of headspace gas samples varied in large scale for different waste types and individual drums. The maximum measured value was 13Bq/L in the case of a non-compacted waste drum. The maximum value for investigated vaults was 8.8 Bq/L. Different radiocarbon activity concentrations were detected in the headspace gas samples from carbon-dioxide as well as methane fractions. The maximum measured activity concentration was $\sim$2700 Bq/L in the case of a non-compacted waste drum, but the typical values were less than 100Bq/L. The maximum ^{14}C activity concentration was 61.8 Bq/L in the investigated vaults. These experimental data could be applied for further calculations of radioactive gas release from different facilities in the course of their safety assessments.

5.3 Application of total soil organic matter dating in kurgan studies

M. Molnár, K. Joó,[a] A. Barczi,[a] Zs. Szántó, I. Futó, L. Palcsu, L. Rinyu

The isolated hillocks called "kurgans" belong to the landscape of the Great Hungarian Plain. Some of them were settlements in the ancient time. This structure of settlements existed at two periods of the prehistoric age: late new Stone Age and early and middle Bronze Age. Nowadays kurgans represent significant value in archaeology, botany, landscape and soil science.

The investigated Csípő-halom is one of the kurgans served as burial place. It is located in the Hortobágy area of the Great Hungarian Plain. Kurgans in Hungary were generally built from surrounding soil. In general after building up the mound the basic rock appeared on the surface around, on which the new soil formation could began. Under the mound the several thousand-year-old soil surface has been buried so it preserves the soil forms that existed in the time of mound's birth, while the distant surroundings of the mound developed forth and shows the marks of soil formation since then.

For pedological description of the mound and its surroundings soil samples were taken by auger sampler. On the basis of their morphological and visual studies the structure and layers of the mound could be reconstructed. Sample selection for ^{14}C dating based on visually observed stratigraphic changes in the important reference layers.

Radiocarbon measurements of soil samples were performed by the Laboratory of Environmental Studies of the INR/HAS. After removing inorganic carbonate fraction and the recent macroscopic biomass fragments, a wet oxidation of previously air-dried soil samples were carried out and the produced CO_2 gas was collected in $Ba(OH)_2$ traps. Using 250g soil sample the bulk combustion pre-treatment method provides enough gas (minimum 0,04 mol) for reliable measurement with the gas proportional counters used for radiocarbon dating.

The measured ^{14}C ages of soil samples from reference points, such as the top layer of the mound (modern soil) (1200 BP), the centre of mound body (anthropogenic layer) (5630 BP), the base layer of the mound (paleosoil) (6040 BP), the near surroundings (810 BP) and the distant surroundings (2210 BP) are in good agreement whit the preliminary archaeological concept for this field and give substantial information about the rate of soil generation processes in this area (Figure 1.).

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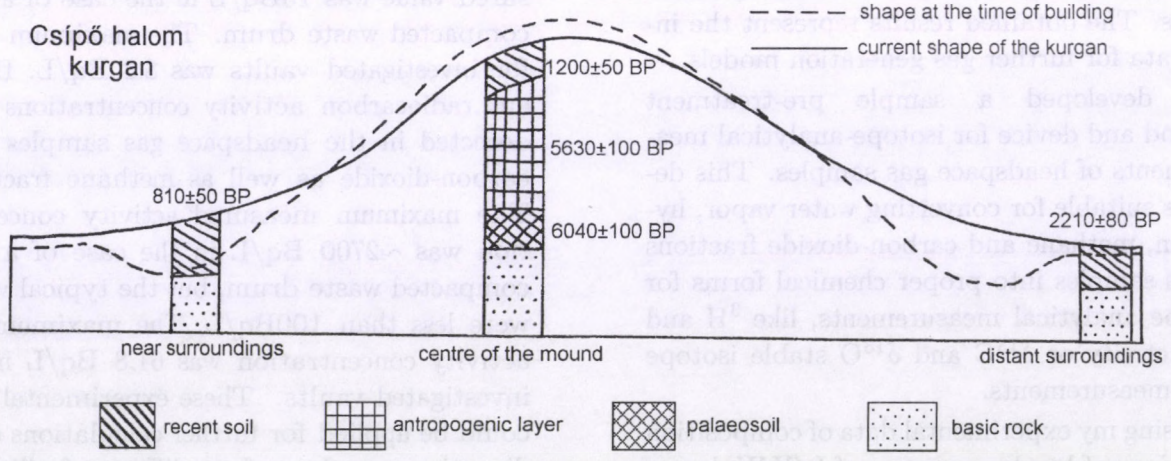

Figure 1. Schematic drawing of recorded main layers in the mound and the surroundings area

5.4 Isotope Studies of a Groundwater-flow System in Granite, Middle Hungary

L. Palcsu, Zs. Szántó, M. Molnár, I. Futó, L. Rinyu, I. Horváth[a], *I. Fórizs*[b]

In Hungary a great research project is going on to find the most suitable site for a low and intermediate level radioactive waste repository. A granite complex located near Bátaapáti, between the Mecsek Mountains and Szekszárdi Hills in Middle Hungary seems to be the best geological formation for this purpose. One of the most important questions in the preliminary safety assessment is how the water moves in the granite rock.

The granite body was produced in the Carboniferous. It is covered by 30-70 metres of Holocene and Pleistocene loess sediment. The peripheral part of the granite is fractured whereas the inside one is unaltered. The flow velocity in the compact granite is very low, about 10^{-9} m·s^{-1}, but in fractured granite it may be higher. The properties of the flow system were investigated by isotope measurements (tritium, ^{14}C, $\delta^{13}C$, δD, $\delta^{18}O$, noble gases, etc.) of groundwater samples from the boreholes drilled 350-400 metres deep into the granite.

Two groups of boreholes were distinguished in the data evaluation: boreholes at the top of the hill, and boreholes in the valley. In the first group the wells were deep (down to 400 m), while the wells in the valley were relatively shallow (180-200 m). All samples, mostly in the shallow ones, contained more or less tritium. It is natural in case of water tables close to the surface, but in the deeper layers it can be the remains of the drilling water. The tritium content decreased with the depth. It can be also seen that the water became older with increasing depth according to the radiocarbon ages, which increased to 21-22 ky. Two boreholes in the valley provided also very old water, the age of the water from 150-160 m in well Üh-30 was the oldest one (38.2 ky). The isotope ratios of deuterium and oxygen became more depleted with increasing depth (−70‰ to −99‰, and −10‰ to −14‰, respectively). This implied that water in deeper layer infiltrated under colder climate. The $\delta^{13}C$ showed an inverse behaviour: the δ-values of carbon isotopes became less depleted with increasing depth (−14‰ to −11‰). The results can be explained with the dissolution of hydro-carbonates from the hostrock containing $\delta^{13}C$ values close to zero. This fact also confirms that the water samples from the deeper region were very old. The radiocarbon ages as well as the decrease of hydrogen and oxygen isotope ratios with increasing depth allow us to suppose that the water in the deepest layer infiltrated before the Holocene.

In three cases it was possible to take noble gas samples. Table 1 shows the helium concentration and isotope ratio ($^3He/\ ^4He$=R divided by the atmospheric ratio R_a) data of the samples, which came from the deepest water layer. These helium data are correlated with the radiocarbon ages: the oldest water (Üh-30 with 38.2 ky) contained the most helium, while the less helium was in the water sample from the shallow borehole (Üh-35, filtered between 30 and 44.2 m).

Table 1: Helium data of water samples of three boreholes from the deepest layer

Sample Identifier	R/R_a	Helium ($ccSTP_{He}/g_{H_2O}$)	^{14}C age (ky)
Üh-35	0.548	$8.7{\cdot}10^{-7}$	-
Üh-27	0.026	$5.0{\cdot}10^{-6}$	14100
Üh-30	0.014	$3.7{\cdot}10^{-5}$	38200

Holocene water can be found in the upper and peripheral part of the granite body, but in the deeper part of the bulk pre-glacial waters appear. Transport model calculations are in progress to determine the flow-paths. On the basis of isotope data we can assume that the water does not flow in the inner part of the granite bulk and so the field is suitable for repository from hydrogeological point of view.

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5.5 Noble Gas Mass Spectrometry in Hydrology and Nuclear Industry (Theses of Ph.D Dissertation)

L. Palcsu

I have initiated the measurement of low-level tritium concentration in water samples by helium-3 ingrowth method in our institute. I have introduced the application of metal containers equipped with metal valve. I have demonstrated the advantage of metal containers in contrast with glass bulbs. I have confirmed the reproducibility of the tritium measurement, and I have proved that the accuracy was higher and the detection limit was lower using my method than in case of other applied techniques. The detection limit is 0.003 ± 0.001 TU.

I have demonstrated the role and the significance of the low-level (¡1 TU) tritium measurement in investigations of aquifer vulnerability on the example of Kótaj aquifer. I have observed that a 163 m deep well contained too much tritium (0.23 ± 0.07 TU) compared to the other wells, which indicated that the well was overexploited.

I have demonstrated the role and the importance of tritium measurement in complex hydrological analyses on the example of aquifer under Püspökszilágy Radioactive Waste Treatment and Disposal Facility. The recharge to the aquifer in the Némedi side of the hill is very limited. The shallow wells at the valley of Némedi and the Szilágyi stream contain water mixed with precipitation. I have assessed that the potential radioactive contamination could move rather toward the Szilágyi stream than toward Némedi stream.

I have taken the time series of the stable isotope ratios and tritium in precipitation in 2001. I have provided hydro-meteorological explanations of the changes in the tritium concentration and stable isotope ratios of rainwater and snow. The T, δD and δ^{18}O values followed the seasonal change. The tritium amount of the precipitation depends on the weather situations as well as the quantity of the precipitation. On the basis of these parameters I explained the short-term changes in tritium concentration.

I have found that the rock containing uranium ore was in connection with a part of the aleurolite formation under the uranium mine in the Mecsek Mountains. On the basis of helium and argon data I could separate a group, in which the water had significant radiogenic argon content and relative low amount of helium. Furthermore, the water in this group were mixed with young water including tritium. On the basis of these observations I have concluded that that part of the alpha-tunnel drilled to the aleurolite formation, where the D5- and D6- sampling points were located, were the most suitable for waste repository, since this area hardly was in connection with the uranium mine-shafts.

By analyses of dissolved noble gases in thermal water (sampled by copper tube) I could declare that these water samples were very old. I have found considerable amount of helium, by which I have determined helium-ages. The helium-ages varied from 44,000 to 3 million years, which were virtually inconsistent with the several 10,000 years radiocarbon ages. The reason of this inconsistency is that the radiocarbon age is an average age of a water body, which may be a mixture of waters of different ages, while the helium content shows a maximum age.

I have detected fission origin xenon isotopes in the heat carrier of the reactor-3 of the nuclear power plant of Paks, which indicated the damage of some fuel elements. On the basis of xenon isotope ratio data I have concluded that the damaged fuel element was installed on summer in 1999.

I have determined the dynamic adsorption coefficient of three different types of activated charcoal for xenon and krypton at room temperature. I have found that the gas retention ability of the charcoal depends on the moisture of the charcoal, the specific surface and the distribution of the pore size.

5.6 The safety assessment methodology used in Hungary for a new LLW/ILW repository

Zs. Szántó, K. Bérci[a)], É. Svingor, I. Futó, L. Rinyu, L. Palcsu, M. Molnár

In Hungary the site exploration for a new LLW/ILW repository implies four stages: regional screening, site selection, site characterization, **safety assessment**. The safety assessment supports the review and judgment of the regulatory authority on the acceptability of the site and supports decision-making on the construction or rejection of the facility.

The safety of radioactive waste disposal facilities can be evaluated by using safety assessment methodology. In this context safety assessment means evaluation of the actual and potential hazards to human health and the environment associated with the natural evolution of a radioactive waste disposal facility over time, and with events, both deliberate and accidental, which could affect its integrity.

At Üveghuta, safety assessment is used to determine the feasibility of the site for construction of the disposal facility, to direct site investigations and to assist in initial decision-making. Moreover, safety assessment has the major objective to assist in system optimization and facility design.

In a safety assessment, it is often important to evaluate the performance of the disposal system under both present and future conditions, including anticipated and less probable events. This means that many different factors must be taken into account and evaluated in a consistent way. This is often achieved through the formulation and analysis of a set of **scenarios**. A scenario is a hypothetical sequence of features, events and processes, and is one of a set devised for the purpose of illustrating the range of future behaviours and states of a repository system, for the purposes of evaluating a safety case.

A common element in many scenario generation methodologies is the initial construction of a list of all features, events and processes (**FEP list**), which could directly or indirectly influence the disposal system and the migration and fate of radionuclides within it.

The general objective of a safety assessment is to determine what impact the disposed waste will have on individuals and their environment as a function of time. This requires consideration of how radionuclides may be released from the disposal facility, the pathways along which they can migrate, and their impacts on human. To achieve this, we have to develop the disposal system.

The disposal system - taking into account its temporal and spatial extent - can be described by the following components:

Internal components: waste characteristics, facility characteristics, engineered barriers (chemical and physical characteristics), human habits and behaviour, doses, near field, the geosphere, the biosphere etc.

External components: other characteristics of the disposal system, geological processes and events, climatic processes and events, future human actions, other factors

These components lead to a three-layer categorisation based on:

- Disposal System Domain: Radionuclide/Contaminant Factors;
- Disposal System Domain: Environmental Factors;
- External Factors.

A fourth category, called the **assessment** context might be associated to these three layers (related to i.e. regulatory time periods, characteristics of critical groups, future human population).

a) ETV-ERŐTERV Rt.

5.7 Decision process and prioritization of safety assessment activites

Zs. Szántó, É. Svingor, I. Futó, L. Rinyu, L. Palcsu, M. Molnár

Within the ASAM project (Application of Safety Assessment Methodologies for Near Surface Disposal Facilities) coordinated by the IAEA the role of the Common Application Aspects Working Group is to investigate the treatment of common issues in post-closure safety assessment of near surface disposal facilities with the aim of providing practical guidance on the treatment of these issues. The working group considers among others the prioritization of safety assessment activities.

The objectives of the work are to:

- define the issues and concepts associated with the prioritization of safety assessment activities;
- summarise the methodological and analytical approaches used to address the prioritization of safety assessment activities in international guidance and in previous assessments;
- document the advantages and disadvantages of the various approaches;
- identify the similarities and differences of the various approaches;
- identify areas of consensus and provide recommendations on prioritization of safety assessment activities.

Decision making is the process of developing a set of possible alternative solutions and choosing one or more alternatives from that set. In general, decision making involves four steps:

- identifying the problem
- generating alternatives
- selecting an alternative
- implementing the solution

Strictly, the prioritization is employed only within the process of selecting an alternative. However, the attributes of different approaches to prioritization cannot be discussed outside the overall decision process.

A draft paper on the decision process, prioritization methods and considerations was written and sent to all group members for review and comment. A questionnaire was sent them also to obtain valuable input from all participants. Feedback on the prioritization questionnaire and review comments on the draft position paper were the basis for the summary of the methodological and analytical approaches used to address the prioritization of safety assessment activities in previous assessments, with special attention given to the similarities and differences between the various approaches.

Within the context of near surface disposal there are a large number of activities that could and should be prioritized at every phase of facility development (additional site characterization, design changes, changes to the waste acceptance criteria, remediation etc). When the need for additional activities is driven by external concerns unrelated to the safety assessment results, a wide variety of approaches have been used and/or were proposed. In general this means the case where the safety assessment results meet the safety standards but the project team believes that additional studies are needed to 'validate' the safety assessment models. These activities include the above mentioned site characterization, facility design changes, etc. and in addition include activities to influence the public opinion regarding to the facility, the safety assessment, and issues involving radiation in general. Identification of which of these activities might be most successful generally relies on a combination of qualitative and subjective judgements combined with quantitative approaches such as uncertainty and sensitivity analysis.

5.8 Determination of elemental abundances in impact materials by micro-PIXE and micro-SRXRF methods

I. Uzonyi, Gy. Szöőr[a)], B. Vekemans[b)], L. Vincze[b)], P. Rózsa[a)], Gy. Szabó, A. Somogyi[c)], F. Adams[b)], Á.Z. Kiss

The most famous and well-preserved meteorite crater in the world is the Barringer Meteor Crater (Arizona, USA), which was created by the Canyon Diablo Meteorite approximately 50,000 years ago. The meteorite is supposed to be a fragment of a small asteroid of our solar system. During the impact event the matter of the projectile mixed with that of the target rocks forming breccias, slag and spherules. Until now our group has devoted much effort to the elemental characterization of impact materials collected from the ejecta layer of the crater. In this report the authors present analytical data on the meteoritic component of some selected magnetizable impact objects (see Fig. 1), thus providing information on the elemental abundances in the primordial planetary matter.

For the non-destructive characterization of the impact materials a combined micro-PIXE and micro-SRXRF technique was applied, which is described elsewhere in this Annual Report.

Figure 2 shows element abundances in the samples normalized to CI chondrite abundances and Fe. This figure suggests that abundances of elements above Fe tend to correlate with their atomic number for all the three samples. The high Nb abundance is characteristic for all of the three samples. It may come from the target rock (possibly from its zircon), especially for sample II and III, and it may be in connection with the troilite (FeS) phase of the Canyon Diablo iron meteorite detected in sample I.

Patterns of the element abundances of the samples are quite similar, however, low abundances of Ge, Sr, Y and Zr in sample I are characteristic. Low Ge abundance in sample I is in agreement with previous measurements on bulk meteorite indicating that abundance of this volatile siderophile element may be depleted by orders of magnitude relative to Fe. Higher Sr, Y and Zr abundances in samples II and III as compared to sample I may be attributed to the incorporated target sedimentary rocks.

(This work was submitted for publication to Spectrochimica Acta Part B).

Figure 1. Image of a studied magnetizable rounded microobject with slag (Sample II).

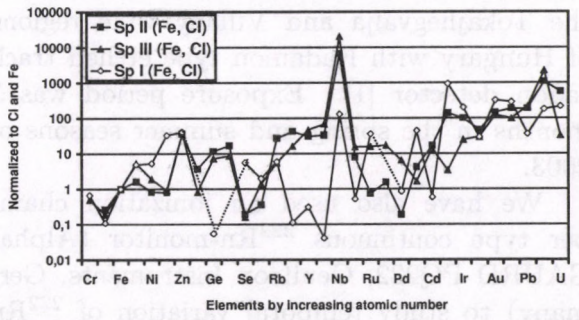

Figure 2. Element abundances in samples I, II and III normalized to CI abundances and Fe.

Supports from the EU 5th FP project (NAS-MICRO-XRF; G4RDCT-2000-00402), Hungarian Research Foundation (OTKA) under contract Nos. A 080, M 041939, M 36324 and the provision of synchrotron radiation facilities at ESRF are gratefully acknowledged. L. Vincze is the fellow of the Belgian Funds for Scientific Research.

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5.9 Radon in the air of wine cellars

I. Csige, I. Hunyadi and P. Szerbin[a)]

Introduction

In spite of the strong interest to the health effects of radon and radon progeny in underground mines, dwellings, and some specific workplaces such as spas and caves there are still some unexplored workplaces seem worth of attention. Such workplaces are the wine cellars, where the atmosphere can contain radon and radon daughters at high concentrations.

The aim of the study was to identify the radon level differences between cellar types, variation of the radon concentration, and to estimate the dose to the workers. The study is in progress, the presented data are the preliminary results of the investigations.

Measurements

We have measured the ^{222}Rn activity concentration in the air of 60 wine cellars in the Tokajhegyalja and Villány wine regions of Hungary with Radamon type etched track radon detector [1]. Exposure period was 3 months in the spring and summer seasons of 2003.

We have also used an ionization chamber type continuous ^{222}Rn-monitor (Alpha-GAURD PQ222, Genitron Instruments, Germany) to study temporal variation of ^{222}Rn activity concentration in a selected wine cellar in the Tokajhegyalja wine region. This instruments also recorded temperature, atmospheric pressure and relative humidity data.

Results and Discussion

Etched track detector data revealed that ^{222}Rn activity concentration in the air of wine cellars spreads over a wild range starting from ambient outdoor concentration of 6 Bqm^{-3} up to 6 kBqm^{-3} characteristic for natural caves [2].

Temporal variation in the selected cellar is presented on Fig. 1. It is clear, that the ^{222}Rn activity concentration in the air of this wine cellar varies inversely with the variation of the atmospheric pressure.

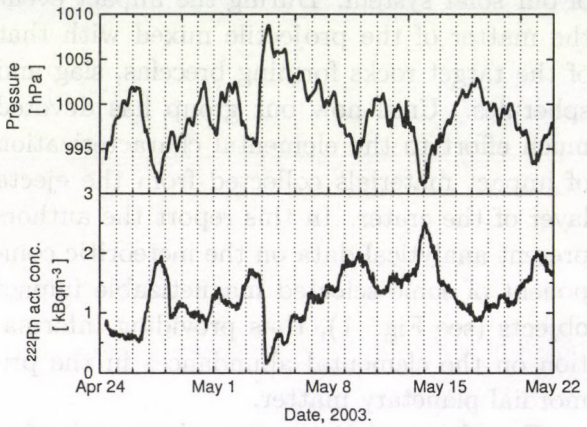

Figure 1. Temporal variation of atmospheric pressure and ^{222}Rn activity concentration in a wine cellar of the Tokajhegyalja wine region in Hungary.

Earlier we have observed similar phenomena in caves connected to the surface with vertical shafts only [2]. It suggests that relatively large volume of pore space of the embedding rock communicate with the volume of the cellar induced by the variation of the atmospheric pressure.

OTKA T-029306 supported this work.

a) OKK-OSSKI, 1221 Budapest, Anna u. 5.

[1] I. Csige *et al.*, Radiat. Measur. 34, 437 (2001)

[2] J. Hakl *et al.*, Radiat. Measur. 28, 675 (1997)

5.10 Investigation of soil erosion in arable land in Hungary using radiotracer technique

Z. Dezső[a)], Á. Bihari[b)], T. Cseszkó[b)] and Sz. Szabó[c)]

Quantitative data on long-term soil erosion rates on agricultural land are an essential requirement for the development of effective soil management and conservation strategies. Despite this, information available on soil erosion rates is very limited world-wide and in particular in Hungary. Although several methods to estimate soil erosion exist, the use of ^{137}Cs and/or ^{210}Pb as fallout radionuclides for tracing soil movement overcomes many of the limitations of the traditional methods. Many studies have been made to establish the relationship between soil erosion rate and the amount of fallout radionuclides found in the soil. Recently, the ^{137}Cs-technique has been widely accepted and is now commonly used for estimating the magnitude of soil loss. In addition, this method has the advantage of providing information on the spatial pattern of redistribution as well.

The principle of the above tracer technique lies in the facts that (i) these radionuclides enter the soil system from the atmosphere, mostly by precipitation (ii) both have a very strong affinity for soil and sediment particles. Hence, the top soil is spiked with a tracer and its fate can be followed for a long period of time. It is the lateral redistribution of the tracer which can be associated with soil erosion or accumulation. The total fallout (reference inventory) at a specific site is a key parameter in evaluating experimental data. The two isotopes differ in both their origin and the temporal pattern of fallout. ^{210}Pb is derived from atmospheric radon and its yearly fallout is fairly constant in time. In turn, ^{137}Cs results from two sources: nuclear weapons tests and fallout from the Chernobyl reactor accident. The former, sometimes quoted as old radiocesium, showed peak fallout in the early sixties and since then it gradually decreased. On the other hand, soil contamination from Chernobyl was a single event in early May of 1986. It is emphasised in many erosion studies based on the ^{137}Cs-technique that a lack of adequate information on the reference ^{137}Cs inventory is an important limitation.

The aim of this work was to study the long-term migration of ^{137}Cs in the Bükkzsérc-Cserépfalu-Bogács triangle area, at the foot of Bükk mountain (NE Hungary) and to test if reliable inventory data could be deduced. The specific genetic soil type here is leptosol with shallow A-horizon and low humus content. The area for sampling on a nearly flat plateau was limited to only a few m^2, in the vicinity of a triangular point established in 1973, for the rest of the area here is arable land. Since the soil is very much stony, several sampling technologies were applied to find the most adequate for obtaining sectioned soil core samples with 2-4 cm resolution.

Five samples were taken in different directions relative to the triangular point, down to a depth of 20-40 cm, area 100-200 cm^2 and 7-15 sectioned subsamples were prepared at each point. The air-dried samples were sieved and the fraction below 1 mm grain size was analysed for ^{137}Cs by gamma spectrometry, using a calibrated high-resolution, low background HPGe coaxial detector. Depending on sample-weight, two geometries were used and samples were counted for 3 hours - 1 day, to provide a precision of 2-5 % at the 90 % confidence level. After correction for self absorption, activity concentrations (AC) were calculated for a given reference time.

Migration of fallout nuclides in an undisturbed stable soil reflects the influence of a range of physico-chemical and biological processes operating in the soil system. Physico-chemical processes, including diffusion and convection, play an important role in the redistribution of ^{137}Cs in soil. If ion exchange is responsible for the adsorption of fallout ^{137}Cs by soil particles and the reaction is reversible, then ^{137}Cs can be replaced by other ions and it re-enters the soil solution. Radionuclides re-

leased from one site in the soil may be transported downwards in the pore water and readsorbed at another site. In solution they can also be subject to molecular diffusion. These processes will be affected by the soil mineralogy and soil chemical and physical properties. As a result, years after the contamination ^{137}Cs is likely to show an exponential depth distribution in a homogeneous undisturbed soil, with a slope depending on time and soil characteristic.

The results obtained for the variation of AC as a function of cumulative mass depth for all samples are shown in Figure 1. One can readily observe that the sample taken south of the triangular point shows an increasing AC with depth, which is certainly the result of ploughing at least once after 1986. The rest of the distributions are very similar and show that soil characteristic abruptly changes at around 12 g/cm^2 (18 cm in depth). This is certainly caused by the very high clay content of soil which, at this depth, blocks water from infiltrating downwards. Furthermore, three of the distributions show that it is likely that two components can be distinguished. The first extends down to about 4-5 g/cm^2 and may represent the soil contamination from the Chernobyl reactor accident. Figure 2 shows the separation of the components for the sample taken NE from the triangular point. The area under the two components gives the ^{137}Cs inventory from the two sources. A preliminary evaluation yields 1870 and 1200 Bq/m^2 for the residual nuclear weapons tests and the Chernobyl contamination, respectively, at our reference time (01/05/2001). The total inventory obtained for the 5 samples lies in the range 2300-3200 Bq/m^2. Further chemical analysis on the soil samples and additional sampling are in progress to refine the inventory data.

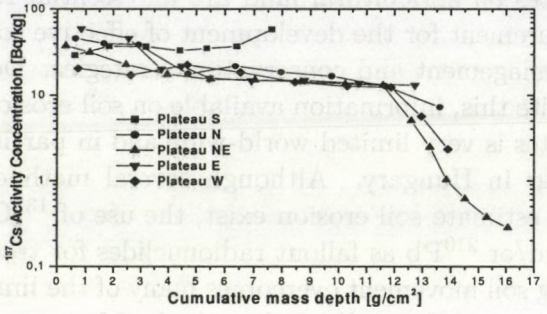

Figure 1. Depth distribution of ^{137}Cs for 5 samples taken near a triangular point

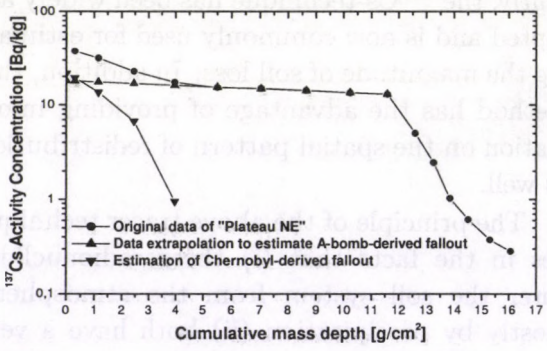

Figure 2. Separation of A-bomb derived and Chernobyl ^{137}Cs-fallout

a) Univ. of Debrecen, Dept. of Environmental Physics

b) Univ. of Debrecen, undergraduate student

c) Univ. of Debrecen, Dept. of Landscape Protection and Environ. Geography

6.1 Catalytic Conversion of ^{11}C-labeled Methanol over Cs-ZSM-5 Zeolite

É. Sarkadi-Pribóczki, N. Kumar[a)], T. Salmi[a)], D.Yu. Murzin[a)], Z. Kovács

The introduction of the radioisotope detection method provides a possibility to follow the ^{11}C-labeled compound and its derivates during the catalytic processes and to identify the ^{11}C-labeled products by radiodetectors. The radioactive method can detect very low amounts of compounds. A thermal conductivity detector was used for demonstration of the inactive compounds formed during catalysis and for the identification of ^{11}C-labeled products. The conversion of ^{11}C labeled methanol have been investigated over the H-ZSM-5 and H-Beta acidic zeolite catalysts [1]. The aim of this work is to investigate the reaction mechanism of the conversion of ^{11}C labeled methanol over basic Cs-ZSM-5 zeolite catalyst and compare the reaction products obtained with that of H-ZSM-5 acidic catalyst.

The Na-ZSM-5 (Si/Al =31) zeolite was synthesized and Cs-ZSM-5 catalyst was prepared by repeated ion-exchange using aqueous solution of cesium nitrate. The characterization of Na-ZSM-5 zeolite was performed using X-ray powder diffraction, scanning electron microscope, X-ray fluorescency and nitrogen adsorption. The ^{11}C-radioisotope ($T_{1/2}$=20.4 min) was produced in cyclotron and used as a gamma emitter (by annihilation of its positron) in the experiments. ^{11}C-labeled methanol was synthesized by classical method. The catalytic experiments were carried out by passing ^{11}C-labeled methanol with He as a carrier gas over Cs-ZSM-5 packed in a micro reactor. After adsorption of the radio methanol, the catalyst was heated up to 330°C. The products of the catalytic conversion of the ^{11}C-labeled methanol were analyzed by radio-gas chromatography (gas chromatograph with thermal conductivity detector on-line coupled with a radioactivity detector). For the identification of the ^{11}C-labeled products inactive compounds were added to the gas samples.

The ^{11}C-labeled products were not removable from the catalyst up to 330°C. In the first minutes the main product (for a short time) was exclusively a ^{11}C-labeled, unidentified intermediate at 330°C. At 20-30 minutes ^{11}C-labeled formaldehyde with ^{11}C-labeled methane, ether and carbon monoxide were detected and after 40-50 minutes, the final products were ^{11}C-labeled CO and small amount of CO_2 at the same temperature. At higher temperature (360°C) the presence of the same products were observed in shorter period.

There are several possibilities regarding the type of intermediates that can be formed in the first minutes of the methanol conversion over Cs-ZSM-5 zeolite. If the process goes to higher carbon number alcohol synthesis, the main product could be ethanol derivates (asymmetric ether, acetaldehyde etc). The other possibility is the formation of glycol aldehyde in the structure of zeolite. But, in the above cases, after 20 minutes mostly formaldehyde was formed together with methane, some dimethyl ether, carbon monoxide and a small amount of hydrocarbons, simultaneously. It is supposed, that the formates, formed in the zeolite, can decompose to formaldehyde and methane.

In our previous experiments, H-ZSM-5 acid zeolite was used for the catalytic conversion of ^{11}C-labeled methanol at 350°C. The main product was ^{11}C-labeled C_3 olefin. Comparing the results of the ^{11}C-labeled methanol conversion over acidic and basic zeolites, there was a very clear difference in the mechanism of catalysis. At Brønsted acid site of H-ZSM-5 zeolite the methanol is converted to dimethyl ether intermediate by dehydration and, with further conversion, to light olefins and paraffins but methane was not detected. At more basic sites of Cs-ZSM-5 zeolite, the methanol is transformed to an unidentified intermediate by dehydrogenation and, with further conversion, to formaldehyde and methane. The Cs-cations can cover most of the acid sites thereby changing the catalytic properties of ZSM-5 zeolite and the methanol is converted to aldehyde on alkali-promoted catalyst. Besides the

methanol dehydrogenation, some hydrocarbon products were also detected which confirmed that Cs-ZSM-5 zeolite still had some acid sites.

For identification of special intermediate compounds, described above, special experiments were carried out to determine the retention time of ^{11}C-labeled methyl ethyl ether from the mixture of ^{11}C-labeled methanol and ethanol over H-ZSM-5 zeolite at 240°C. The main products were ^{11}C-labeled methyl ethyl ether. The results of the gas chromatographic analysis showed that the ^{11}C-labeled intermediate, obtained over the Cs-ZSM-5 basic zeolite, was not ^{11}C-labeled methyl ethyl ether. To identify the other intermediates, namely the formation of glycol aldehyde from methanol and formaldehyde, is in progress.

Although Cs-ZSM-5 is mostly a basic zeolite forming formaldehyde by dehydrogenation, it also retains features of a weak acid zeolite producing dimethyl ether and hydrocarbons by dehydration.

Acknowledgements

This work was financially supported by the Hungarian Scientific Research Fund No. T031764.

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[1] E. Sarkadi-Pribóczki, N. Kumar, T. Salmi, D. Yu. Murzin, Z. Kovács, Catalysis Letters (in press)

7.1 Proton Therapy Beam Dosimetry with Silicon CMOS Image Sensors

A. Sanchez-Crespo[a,b], A. Kerek[c], W. Klamra[c], J. Molnár, L.-O. Norlin[c], B. Skatt[a], E. Grusell[d], D. Novák, A. Sipos, J. Van der Marel[e] and J. Végh

In a previous publication [1], it has been shown how neutron and proton beams in a quite broad energy interval, could be simply monitored with a position sensitive CMOS image detector [2]. The monitoring is based on detection of charged fragments from nucleon induced nuclear reactions. Nuclear reactions give rise to a variety of characteristic heavy recoil nuclei and secondary light particles, e.g. ^{25}Al and an alpha particle from the reaction $^{28}Si(p,\alpha)^{25}Al$. The impinging particle fluence rate at the detector surface could be obtained from the direct read out of the CMOS image sensor chip, by counting the number of spots per image frame and applying a factor correcting for detection efficiency for the used particle energies.

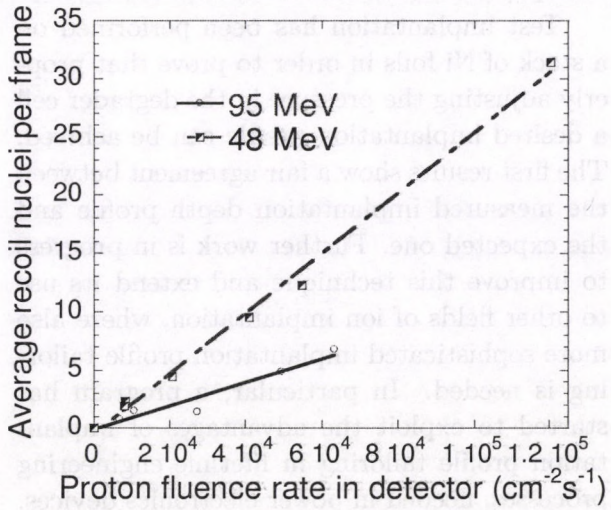

Figure 1. The probability function for the number of recoil nuclei per (20 ms) image frame as a function of proton beam energy and intensity.

Figure 1 shows the cumulative histogram distribution of the experimentally determined number of recoil nuclei per video frame as a function of 48 MeV proton beam intensity for perpendicular incidence (including Gaussian fits). Shown are the number of recoil nuclei produced per frame (20 ms) as a function of proton current. In Figure 2, the corresponding most probable number of recoil nuclei per image frame as obtained from the Gaussian fits, is shown as function of proton current and energy.

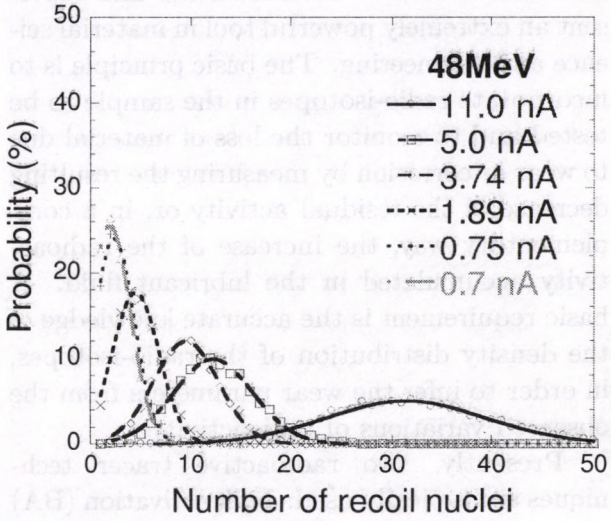

Figure 2. Linear relationship between the proton fluence rate and the most probable number of proton induced nuclear reactions.

The direct read out, the lack of pile up effects, the stability of the signal, the detector linear response with proton energy and current and the very low costs of the device could make the CMOS detector a good candidate in addition to other well established detectors for proton radiation dosimetry.

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e) Stichting ASTRON, Zwiggelte, Holland

[1] A. Sipos, E. Grusell, A. Kerek, W. Klamra, J. Molnár, L.-O. Norlin, D. Novák, A. Sanchez-Crespo, J. Van der Marel and J. Végh. NIMA 509 (2003) 328.

[2]VISION VM 5402 Camera Module datasheet.

7.2 Wear measurements by means of ^{7}Be implantation

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Radioactive tracer techniques are nowadays routinely used for non contacting, on line wear and corrosion measurements and represent an extremely powerful tool in material science and engineering. The basic principle is to incorporate radio-isotopes in the sample to be tested and to monitor the loss of material due to wear or corrosion by measuring the resulting decrease of the residual activity or, in a complementary way, the increase of the radioactivity accumulated in the lubricant fluid. A basic requirement is the accurate knowledge of the density distribution of the radio-isotopes, in order to infer the wear parameters from the observed variations of radioactivity.

Presently, two radioactive tracer techniques are typically used: bulk activation (BA) and surface-layer activation (SLA). In both cases, radio-isotopes are produced directly in the sample by irradiating it with neutrons, for BA, or light charged particles, for SLA. A common problem of these techniques is that their application depends on the material to be tested (activation cross section and resistance to radiation damage). Moreover, the radio-isotope depth distribution is governed by the energy dependence of the activation cross section, that strongly limits the possibility of optimising the distribution in view of specific requirements of the test.

Radioactive ion implantation (RII) is a possible solution to such problems. In this approach a radioactive ion beam (RIB) is used to implant radio-isotopes in the surface layer of the sample. The implantation depth is determined by the beam energy and the stopping power of the radioactive ion in the sample: therefore a proper modulation of the ion beam energy during the implantation in a given material allows a quite wide range of possible radio-isotope depth distributions. The drastic reduction of the radiation damage allows application of RII in principle to any material, therefore providing a powerful tool for comparative studies.

At the 3MV tandem accelerator of the University of Naples a ^{7}Be beam was developed to investigate the astrophysically important reaction ^{7}Be(p,γ)^{8}B [1]. The radioactive ^{7}Be material has been produced at the cyclotron of the ATOMKI. A novel setup on the Naples RIB facility allows control of the ^{7}Be beam energy making use of an energy degrader gas cell with adjustable pressure. With this technique the requirements of a RII facility are fulfilled thus the ^{7}Be beam can be used not only for nuclear astrophysics but also for wear merasurements.

Test implantation has been performed on a stack of Ni foils in order to prove that properly adjusting the pressure in the degrader cell a desired implantation profile can be achived. The first results show a fair agreement between the measured implantation depth profile and the expected one. Further work is in progress to improve this technique and extend its use to other fields of ion implantation, where also more sophisticated implantation profile tailoring is needed. In particular, a program has started to exploit the advantages of implantation profile tailoring in lifetime engineering processes, needed in power electronics devices, allowing to modify in a selective way the value of the recombination lifetime in semiconductor materials.

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c) Ruhr Universität Bochum, Bochum, Germany

[1] L. Gialanella *et al.*, Eur. Phys. J. A 7, (2000) 303.

7.3 Proton Beam Micromachined Gear-wheels and Racks

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Proton Beam Micromachining [1,2] has been performed on the nuclear microprobe of the Institute [3] over the past year.

The beam energy was typically 2 MeV, the spot size was 2-3 μm at 10-20 pA current. The scan size ranged from 100 to 1000 μm. The largest gear-wheel was 500 μm in diameter, and the corresponding rack was 1000 μm long.

The samples were irradiated on a 50 μm thick PMMA foil. This is such thickness that is still self supporting, and it is thin enough for the beam to penetrate through at the used energy.

A typical irradiation pattern for a gear-wheel structure is shown on *Fig. 1.a)*. Part *b)* of this figure shows the structure before etching, and *c)* shows it after etching.

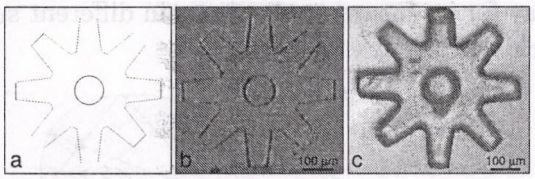

Figure 1. Gear-wheel. a) design, b) DIC microscopy photo before etching, c) after ethcing

Differential Intereference Contrast (DIC) microscopy was used before chemical developing, since the polymer samples change their refractive index due to proton beam irradiation. *Fig. 2.* shows a rack structure after irradiation before etching.

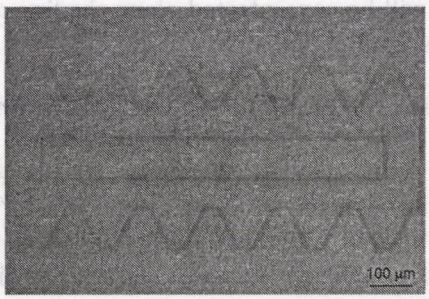

Figure 2. DIC microscopy photo of the irradiated rack

The etching was done at 23-25°C for 1 hour using the following formula: 60% Diethylene Glycol Monobutyl Ether, 20% Morpholine, 5% Ethanolamine, 15% Water. The samples were continually observed under an optical micrscope during the ethcing process. It was found that the largest structures started to fall out of the PMMA foil after 35 minutes of etching time. The smaller structures remained in the foil longer. *Fig. 3.* shows a collection of gear-wheels and racks after etching. These miniature mechanical parts are now removed from the PMMA film so the next step is to build a "machine" with the use of these gear-wheels and racks.

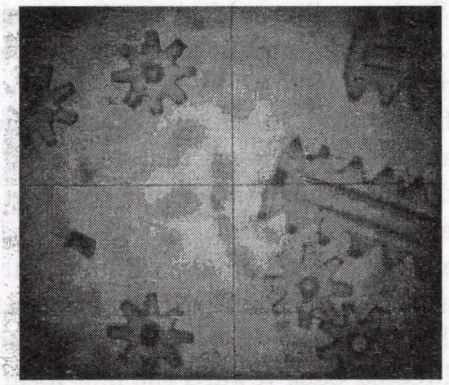

Figure 3. A collection of miniature 3D gear-wheels and racks. These gear-wheels are 500 μm in diameter, and the racks are 1000 μm long.

Acknowledgements

This project was supported by OTKA A080 and F42474. One of the authors (I.R.) is a Bolyai fellow.

a) Univ. of Debrecen, Dept. of Environmental Physics

b) Univ. of Debrecen, Dept. of Solid State Physics

[1] I. Rajta, I. Gomez-Morilla, M.H. Abraham, Á.Z. Kiss, NIMB 210 (2003) 260.

[2] J.L. Sanchez, J.A. van Kan, T. Osipowicz, S.V. Springham, F. Watt, NIMB 136 (1998) 385.

[3] I. Rajta, I. Borbély-Kiss, Gy. Mórik, L. Bartha, E. Koltay, Á.Z. Kiss, NIMB 109/110 (1996) 148.

7.4 Ellipsoid as a possible tool in physics research

Z. Gácsi

An ellipsoid of revolution is the geometrical locus of points in space the coordinates of which satisfy the following equation:

$$(x/a)^2 + (y/b)^2 + (z/c)^2 = 1$$

Ellipsoids have wide variety of use. In 1950 a patent was granted to the application of a semi-ellipsoid for medical purposes. [1] More recent medical use is in kidney stone treatment (lithotripsy). [2] Nowadays, artifical diamonds are also produced commercially in ellipsoid furnaces by the Chemical Vapor Deposition (CVD) method.[3]

For the present purposes, consider the case when a=b<c in the above equation. This is a prolate ellipsoid, akin to an American football. Such an ellipsoid has two focal points inside. An arbitrary radiation or wavefront leaving one of the focal points in any direction may be reflected from the inner surface of the ellipsoid and then will reach the other focal point. The distance thus travelled is constant, independent of the direction of emmission. The radiation, after reaching the second focal point, will travel further hitting the inner surface of the elliposid where it may be again reflected and directed back toward the first focal point. It is remarkable and is to be emphasized that after only a few reflections, all the radiation is concentrated to a very small space in the ellipsoid along the line connecting the two focal points. As a consequence of this, high energy concentration can be produced. This can be achieved by a resonant generation of shock waves in one or both of the focal points, at carefully adjusted frequencies. In appropriate circumstances, this may lead to such a high mulecular kinetic energy which is in the range of a few tens of a keV. Such an energy may be enough for e.g.: deuterium ions to fuse in collisions with each other and produce 2.45-MeV neutrons.

In order to test this, a detailed study of shock-wave propagation, of Hugoniot relations between the characteristic parameters, and of the optimization of several factors are necessary. Such factors include the chemical and physical composition of the medium for the shock-waves (gas vs. liquid; noble gases, heavy water; contamination and bubble-free homogeneity, etc.), mechanical feature of the inner surface of the ellipsoid, the method of shock-wave generation, its characterization via measurement of pressure dynamics at different points inside the ellipsoid, particularly along the line of the focal points, tuning the wave generation to achieve resonant energy feeding to the system.

A systematic study is being initiated and carried out [4] to learn more about the unique behavior of this simple tool and to pave the way for its future applications in different subfields of physics research.

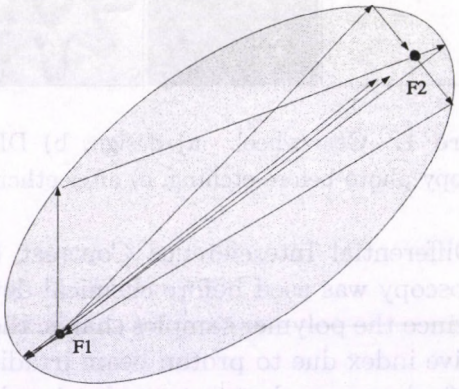

Figure 1. Waves are reflected at the inner surface of the ellipsoid, and after only a few reflections the waves will be concentrated along the line connecting the focal points.

[1] Frank Rieber, US Patent No. 2559277. New York, 1950,

[2] L. Howle *et al.*, SIAM Review, **40**, 356, 1998 and refs. therein,
see also: http://www.domedtech.de/

[3] http://www.cvd-diamond.com/tfdiderd /frames_e.htm

[4] Z. Gácsi, to be published

7.5 Decelerating system for highly charged energetic heavy ions to study the potential sputtering phenomenon

F. Ditrói, S. Biri, J.D. Meyer[b] and K. Stiebing[b]

In the frame of inter-governmental cooperation between our institute and the Institut für Kernphysik of the J.W. Goethe University the sputtering phenomena with highly charged heavy ions was studied experimentally in the ECR (Electro Cyclotron Resonance) Laboratories of both institute. To investigate the pure potential sputtering we had to get rid from the kinetic contribution. For this purpose a special decelerating lens system was designed by using the SIMION Version 7. electron-optical simulation package (Fig. 1.). The devices consist of a couple of angular electrodes, where on the middle 3 electrodes the accelerating voltage is connected. We also superposed a variable voltage on these electrodes to make possible to walk around the accelerating voltage. The first and last electrodes were connected to the earth potential and the voltage between them and the middle electrodes was divided stepwise by using an resistor cascade. In the middle plane a wire-grid (transmission 95%) was also used to improve the lense geometry. As test beam Ar^{8+} particles were used with an energy of 80 keV. In this case the accelerating potencial was 10 kV. Figure 1 shows the case of 79.9999 keV Ar^{8+} particles.

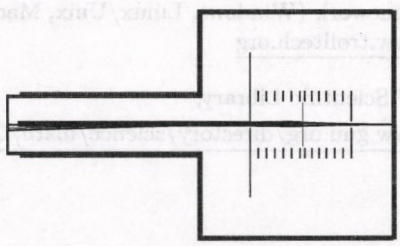

Figure 1. Simulated path of 79.9999 keV Ar^{8+} ions

Decreasing the bombarding energy (or rather increasing the grid potential we got the ion paths shown in Figure 2. It means that all the ions are stopped or turned back at the middle grid when the energy is lower than the threshold corresponding to the maximum decelerating potential.

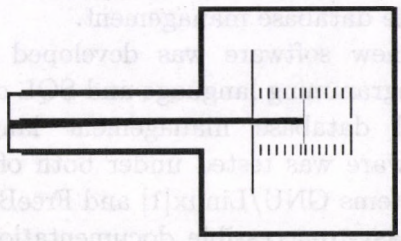

Figure 2. Simulated path of 79.999 keV Ar^{8+} ions

The above system was manufactured and installed on the analyzed beam-line of the Frankfurt ECR ion source. The test runs were performed also with Ar^{8+} ions with an accelerating voltage of 10 kV. For the superimposed voltage a special remote controlled power supply capable for an output of 100 V (added or subtracted)was used. The ion current after the decelerating system was monitored in a Faraday cup and registered automatically, parallel with the maximum decelerating potential. The results of the SIMION simulations could be reproduced taking into account the energy with of the ion beam. Our system proved to be suitable for potential sputtering investigations.

Acknowledgments

This work was partly supported by the Alexander von Humboldt Foundation and by the Nr. D-37/00 research cooperation project supported by the Research and Development Division of the Hungarian Ministry of Education and its foreign contract-partner, the BMBF in the framework of the German-Hungarian inter-governmental scientific and technological collaboration

a) Institut für Kernphysik, J.W. Goethe University, Frankfurt, Germany

7.6 Software Development for ^{14}C Gas-proportional Counter System

L. Rinyu, I. Futó, M. Molnár, L. Palcsu, É. Svingor, Zs. Szántó

The present controlling and evaluating software was developed by Attila Sáhi, in 1991. This software has some basic problems - for example halting date handling, and limited data storage, etc - which has forced to develop a new controlling and evaluating software with up-to-date database management.

The new software was developed under C++ programming language and SQL object-relational database management language. The software was tested under both of operating systems GNU/Linux[1] and FreeBSD[2], for the easy-to-accessible documentation, the useful complete description and the savings.

For representation of array in SQL-language PostgreSQL[3] database management system has been chosen which includes check constraint what solves this problem. The SQL-language makes the easy and quick search possible in the database by different conditions. The PostgreSQL ORDBMS is provided under GPL[1]. The shapes of data tables render improvement possible and extend the database over all kinds of sample treatments and measurements applied in our labs.

Trolltech Qt multiplatform C++ application framework[4] was used to form the user interface. This software package is free under Linux/Unix and Mac OS X operating systems and is provided under both the Q Public License("QPL") and the GPL[1]. Under Windows platforms only commercial versions are supported. The package contains a project management software, an easy to use form designer - like Borland Deplhi/C++ Builder RAD -, html based documentation, translation tools for multi language software development and SQL database interface.

The shapes of user interface is similar to the former software but it is suitable for the demands of present days. The program is able to receive data of the previous system and convert these data to the SQL database system. The experiences accumulated since 1991 were used up in development of data processing. For instance the utilization of GNU Scientific Library[5] enlarges the possibilities of determinations of standard and background values for the different counter tubes.

The next stages in the development is to write device driver under FreeBSD[2] for the necessary PC-cards and to realize the communication between the controlling system - which works on industrial personal computer - and the user interface - includes the evaluating system - with TCP/IP protocol.

[1] GNU/Linux operating systems and GNU General Public License, www.gnu.org

[2] FreeBSD operating system, www.FreeBSD.org

[3] PostgreSQL object-relational database management system, www.postgresql.org

[4] Trolltech Qt multiplatform, C++ application framework (Windows, Linux/Unix, Mac OS X), www.trolltech.org

[5] GNU Scientific Library, www.gnu.org/directory/science/math/GNUsl.html

7.7 Visualization of Heavy Ion Induced Charge Production in a CMOS Image Sensor

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In a previous publication [1], we analysed the effect of the impinging neutron and proton beams on a commercial CMOS video image sensor[2]. Because the bright spots are caused by the charges created by the interaction of these secondary particles with the detector material, one analyzes the effect of some mixture of secondary projectiles. Recently the effects of these secondary particles on the image sensor have been systematically investigated as function of energy and type of ion.

The simple model of the image sensor used (after removing the cover glass from its top) comprises a 2 μm thick protective layer (Si_3N_4), a 20 μm sensitive layer (Si) and a thick but insensitive bulk (Si) layer, see the left figure. The ranges in silicon of these secondary particles vary from a few microns to half a millimeter, depending on the energy and type of the particles. Also, the stopping power varies considerably as the projectiles slow down, so the charge creation along their tracks depends heavily on the type and energy. Particles that hardly enter the sensitive layer or high-energy projectiles, which traverse the sensitive layer, deposit less energy. This ΔE type detector behaviour is nicely illustrated in the α brightness histograms (see right figure) where the maximum brightness is obtained for 4 and 6 MeV.

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e) Stichting ASTRON, Zwiggelte, Holland

[1] A. Sipos, E. Grusell, A. Kerek, W. Klamra, J. Molnár, L.-O. Norlin, D. Novák, A. Sanchez-Crespo, J. Van der Marel and J. Végh. NIMA 509 (2003) 328.

[2]VISION VM 5402 Camera Module datasheet.

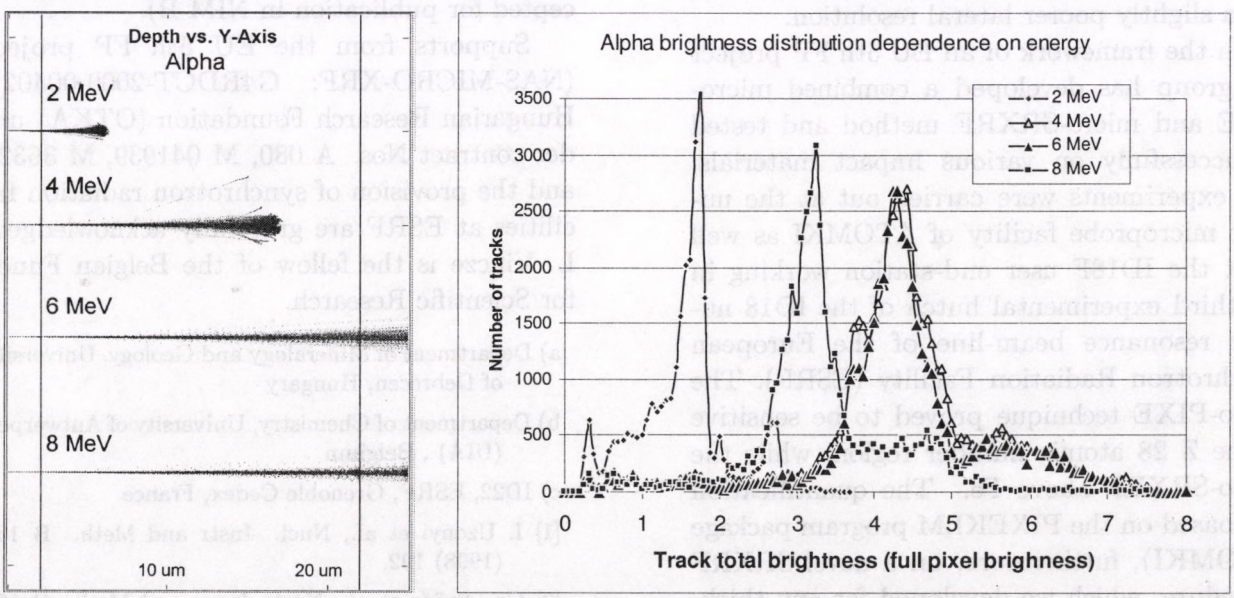

Figure 1: Ranges and brightness distributions of α projectiles of different energy

7.8 A combined micro-PIXE and micro-SRXRF method for the characterization of impact materials

I. Uzonyi, Gy. Szöőr[a)], P. Rózsa[a)], B. Vekemans[b)], L. Vincze[b)], F. Adams[b)], M. Drakopoulos[c)], A. Somogyi[c)], Á.Z. Kiss

In recent years our group has made significant efforts for the characterization of various impact materials collected from different geographical sites of the Carpathian Basin and around the Barringer Meteor Crater, Arizona. Until now we have published results on various glassy spherules extracted from Carpathian Mesozoic lime stone by micro-PIXE method [1] and on magnetic spherules of the Barringer Meteor Crater using SEM-EDS and micro-PIXE techniques for the determination of siderophile elements, carbon and oxygen content [2,3]. Early experiments showed, that the sensitivity of micro-PIXE is not satisfactory for the determination of medium and high atomic number trace elements such as the important platinum group metals (Ru, Rh, Pd, Os, Ir, Pt). In this atomic number region the non-destructive Synchrotron Radiation X-Ray Fluorescence (micro-SRXRF) technique offers excellent sensitivity down to the sub-ppm level and deeper probing depth for the elements as compared to micro-PIXE. However, SRXRF has a slightly poorer lateral resolution.

In the framework of an EU 5th FP project our group has developed a combined micro-PIXE and micro-SRXRF method and tested it successfully on various impact materials. The experiments were carried out at the nuclear microprobe facility of ATOMKI as well as at the ID18F user end-station working in the third experimental hutch of the ID18 nuclear resonance beam-line of the European Synchrotron Radiation Facility (ESRF). The micro-PIXE technique proved to be sensitive in the Z 28 atomic number region, while the micro-SRXRF above Fe. The quantification was based on the PIXEKLM program package (ATOMKI), furthermore, on a novel SRXRF procedure, which we developed for any thickness heterogeneous materials. The concentrations of elements are calculated from the normalized characteristic X-ray yields using the following expression:

$$C_i = K_i(matrix, geometry, ...)\frac{N_{char}}{N_{Comp}}$$

The N_{char}/N_{Comp} intensity ratio was determined by the AXIL program package. For normalisation the Compton scattered radiation is used, which can be considered practically as an internal standard. Thus the influence of the matrix absorption, sample heterogeneity and form-problems on the concentration determination is significantly decreased. The calibration factor K_i is calculated numerically using PIXE concentrations for the major and minor elements as well as various fundamental and experimental parameters.

Our methodological developments made it possible for the first time to carry out quantitative analysis for more than 40 major minor and trace elements by these complementary methods providing new perspectives for the interpretation of the formation mechanism of impact materials. (This work has been accepted for publication in NIM B).

Supports from the EU 5th FP project (NAS-MICRO-XRF; G4RDCT-2000-00402), Hungarian Research Foundation (OTKA) under contract Nos. A 080, M 041939, M 36324 and the provision of synchrotron radiation facilities at ESRF are gratefully acknowledged. L. Vincze is the fellow of the Belgian Funds for Scientific Research.

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[1] I. Uzonyi et al., Nucl. Instr and Meth. B 139 (1998) 192.

[2] Gy. Szöőr et al., Nucl. Insr. and Meth. B 181 (2001) 557.

[3] Z. Elekes et al., Nucl Inst. and Meth. B 190 (2002) 291.

7.9 VME based data acquisition system for multi-parameter measurements

A. Krasznahorkay Jr.

A new VME based data acquisition system (VDA) was developed for multi-parameter measurements in nuclear physics. It works together with the **paw++** program – using its libraries – developed at CERN for interactive data analysis [1].

The system uses a Wiener A32/D32 VME bus controller [2] connected to a PC running Linux. The program at this time is able to access two types of VME devices: a Silena 32 channels, 12 bit ADC (9418-6V) [3] and a Silena 32 channels, 12 bit TDC (9418-6T) [4].

The functioning of the program is demonstrated in the figure.

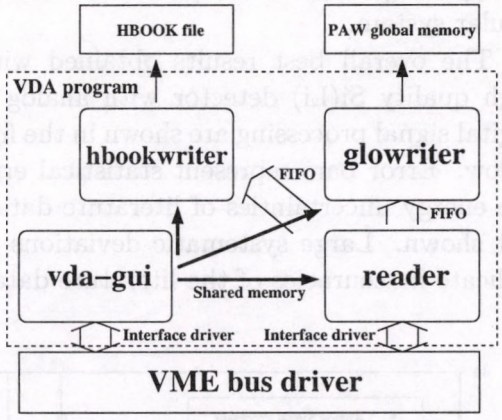


Figure 1. Block diagram of the VDA system.

The device driver for the VME interface was downloaded from the web-page of the manufacturer [2]. It was written in standard C.

The data acquisition system consists of 4 separate programs. All of them were written in C++. The user starts the executable "vda-gui", which starts the graphical user interface of the program. The GUI uses the Qt graphical programming library version 3.1.x or newer [5]. Here the user can set up the data acquisition's details. This includes: devices included in the setup and their specific settings, channels to be read, identifier of each channel, data processing programs to be started. All of these can be set up graphically.

The data acquisition process can also be controlled from the GUI. A separate window exists to start and stop the processing programs ("reader", "glowriter", "hbookwriter"), and start and stop the acquisition.

The GUI transmits the details about the data acquisition to the processing programs using a shared memory segment, in a Linux specific way. The "reader" program transmits the read data to the other processing programs using two separate FIFOs, also in a Linux specific way.

The "glowriter" program writes the read data to the shared memory block of **paw++** for continuous monitoring.

The "hbookwriter" program writes the read data event-by-event to an HBOOK file (specified in the GUI).

Recently the acquisition system was successfully used in a $\gamma\gamma$-coincidence experiment, performed with 3 high resolution clover detectors [6]. 54 channels have been read out with an average rate of 3 kHz giving a dead time of less than 10%.

[1] http://wwwasd.web.cern.ch/wwwasd/cernlib/

[2] http://www.wiener-d.com

[3] http://www.geocities.com/silena_spa/Fairbus/9418-6V.htm

[4] http://www.geocities.com/silena_spa/silena/products/camacandvme/94186t.htm

[5] http://www.trolltech.com

[6] A. Krasznahorkay et al., ATOMKI Ann. Rep. 2003

7.10 Energy calibration of semiconductor X-ray detectors

G. Kalinka and M. Novák[a)]

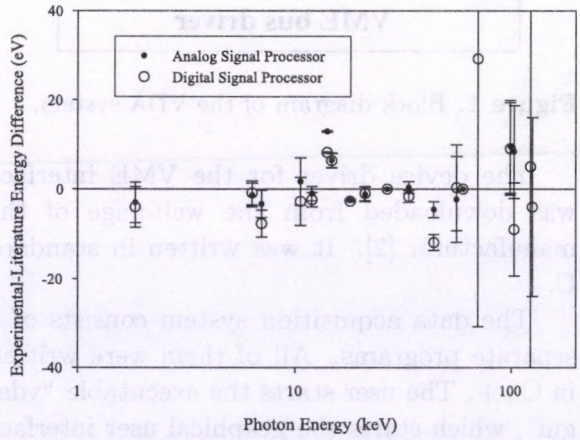
Energy calibration of semiconductor X-ray detectors is usually considered to be a problem-free task, it is routinely carried out by first, second, etc. degree polynomials. With the improvement of the performance of spectrometer systems, and the availability of sophisticated peak fitting softwares, the precision of peak parameter estimation has been much increased. This ability in our practice has revealed discrepancies in accurate energy determination and led to the need of deeper understanding.

As a starting approach we have reassessed numerous previously acquired spectra taken under a very wide range of conditions. The detectors included Si(Li)s of different size, geometry, entrance contact and manufacturer, small Ge(Li), HP Ge, SiGe(Li), thin Si pin and drift detectors and a CdZnTe one. Thick detectors were cooled by liquid nitrogen, whereas thin ones used moderate Peltier cooling. The preamplifiers were of passive (resistor-) and active (light-, drain- and transistor-) feedbacked charge sensitive or simple voltage sensitive types. The signal processors ranged from simple semigaussians through time variant analogs to digital ones, with or without a zero peak. MCAs used with analog processors were of Wilkinson or sliding scale types, with channel widths set to 5-30 eV. Since it is a major objective to standardize ^{241}Am for universal (energy, efficiency and resolution) calibration purposeses, whenever it was possible, spectra of different ^{241}Am sources, extending up to 60-100 keV, or even beyond, were favoured. Besides several γ-rays, this isotope emits the K,L,M series of Np, and can also excite the X-rays of Am and other constituents of source holders. A further calibration point with Si detectors was the SiK edge jump in the Compton continuum.

To our best knowledge the measured spectral amplitude can be expressed as the product of ε, the mean energy to create one hole-electron pair allowing for weak electric field induced enhancement, the charge collection efficiency, the overall electronic gain, the ballistic deficit and the ADC conversion factor.

The preliminary results are rather diverse: they range from fairly linear through smoothly varying to rather weird characters. A short conclusion is that reliable evaluation of a full ^{241}Am spectrum is rather tedious, but can provide $\leq 5\ eV$ accuracy over most of the entire energy range, almost independent of the particular system.

The overall best results obtained with a high quality Si(Li) detector with analog and digital signal processing are shown in the figure below. Error bars represent statistical errors, the energy uncertainties of literature data are not shown. Large systematic deviations may indicate inaccuracies of the literature data.



b) undergraduate student, Debrecen University

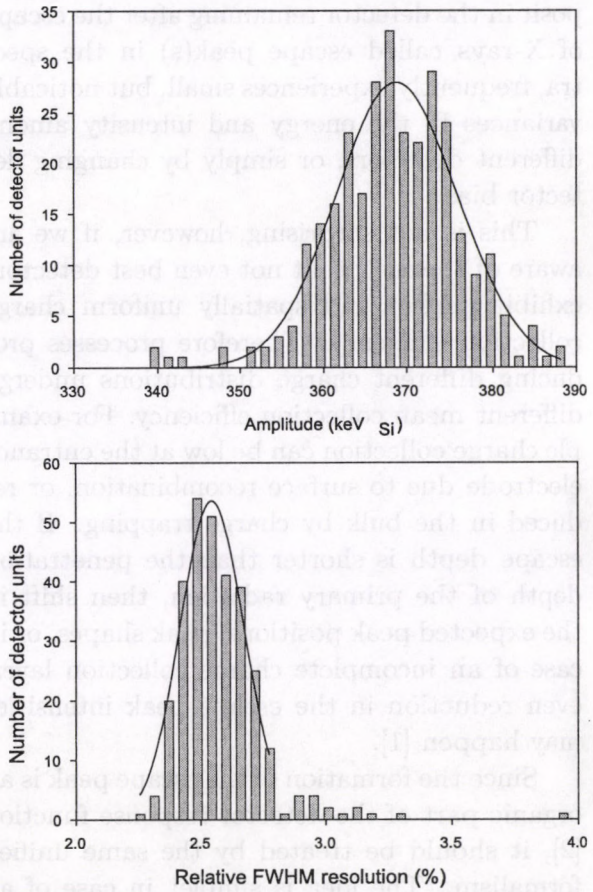
7.11 Progress report on the construction of a 312 element CsI(Tl) scintillator + Si pin photodiode light charged particle array

G. Kalinka, Z. Elekes[*,a)], Zs. Fülöp, J. Gál, G. Hegyesi, J. Molnár, T. Motobayashi*[a)], *A. Saito*[b)] *and Y. Yanagisawa*[a)]

A collaboration for the construction of a NaI(Tl), BGO and CsI(Tl) hybride arrays to be used at RIKEN RI Beam Factory in the near future to detect gamma-rays and charged particles (CP) from fast moving nuclei produced in nuclear reactions with radioactive beams started in 1991 [1].

The CP subsystem consists of 312 Cs(Tl) crystals coupled to silicon photodiodes in a hemispherical arrangement, four detectors packed together with their own preamplifiers in each of the 78 parallelepipedic thin walled aluminum containers. The individual CsI(Tl) crystal size is $16 \times 16 \times 55$ mm^3 in order to stop light particles with approximately 110 MeV/u. Actually one squared end is tapered in 5 mm length to fit it to a 10×10 mm^2 photodiode. Based on our one decade long experience with the three generations of the similar DIAMANT system[2], EPOTEC-302 glue has been used for their attachment. As light reflector for the long side surfaces, 2 layers of the 70 μm thick 3M's Multilayer Mirror Film has been selected for its high (>98.5 %) reflectivity, long term stability, compactness and the easily reproducible technology of wrapping with it [3].

The quality of the applied technology can be assessed from the figure, which summarises the test performance results obtained with 5.5 MeV α particles for all 312 detector units completed, in the form of amplitude and resolution distribution graphs. The light collection is so well reproducible that the amplitude distribution is only slightly wider (FWHM=3.2 %), then the width of a "mean" individual spectral peak (2.5 %). This means, that practically no gain matching in the array is necessary, provided the system electronics will exhibit similar performance. During this test all detectors were covered with thin Aluminized Mylar front reflector. By replacing it with MM film, which poses no problem in the detection of high energy light particles, the amplitudes can be increased by ~20 %, significantly improving thereby the energy resolution for that energies. The average value of the low energy background continuum for 5.5 MeV α, not shown in the figure, is less than 3%.



*) on leave from ATOMKI, Debrecen, Hungary

a) RIKEN, Wako, Saitama, Japan

b) Rikkyo University, Tokyo, Japan

[1] H. Hasegawa et al., RIKEN Accel. Prog. Rep. 35 (2002) 169

[2] J.N. Scheurer, Int. Conf. Future of Nuclear Spectroscopy, Aghia Pelagia, Crete, World Scientific (1993), p.371

[3] Z. Elekes et al., Nucl. Phys. A719 (2003) 316C

7.12 Model for characteristic X-ray escape process related spectral distributions in semiconductor detectors

G. Kalinka

Under the influence of ionizing radiation to be measured, characteristic X-rays of the detector material can be excited and emitted into the surrounding space. For an outer observer, there is no doubt, the energy- and intensity-distribution of the emitted radiation is constant under identical conditions. A detector user, however, who measures the energy deposit in the detector remaining after the escape of X-rays called escape peak(s) in the spectra, frequently experiences small, but noticable variances in the energy and intensity among different detectors, or simply by changing detector bias.

This is not surprising, however, if we are aware of the fact, that not even best detectors exhibit perfect and spatially uniform charge collection efficiency. Therefore processes producing different charge distributions undergo different mean collection efficiency. For example charge collection can be low at the entrance electrode due to surface recombination, or reduced in the bulk by charge trapping. If the escape depth is shorter than the penetration depth of the primary radiation, then shift in the expected peak positions, peak shapes, or in case of an incomplete charge collection layer, even reduction in the escape peak intensities may happen [1].

Since the formation of the escape peak is an organic part of the detector response function [2], it should be treated by the same unified formalism. The idea is simple: in case of an ideal, nondiscriminating time invariant signal processing system, for thermalized charge carriers each space coordinate can be characterized by a collection efficiency $\eta(\vec{r})$, its standard deviation $\sigma_{coll}(\vec{r})$, and a ballistic deficit $B(\vec{r})$ value. Therefore, if the spatial distribution of thermalized carriers is known following the interactions of an incoming photon with the detector, the response can be calculated. Due to the finite range of the electrons and photons created during the energy deposition process in the detector, the original distribution $R(\vec{r}, E) = \delta(\vec{r}_0 - \vec{r})\delta(E_0 - E)$ of a truly monoenergetic primary photon transformes into the energy deposition probabilility $R(E_0, \vec{r}_0, E, \vec{r})$, $\vec{r}_0$ being the primary interaction point of the incoming photon. The key issues here are, that instead of a pointlike energy deposition, the primary energy is dispersed over the entire detector volume and even beyond it, and that this can be described by only a space and energy coordinate dependent distribution. The R distribution function is the superposition of different subprocesses of different orders. The most important of them are P,P-EE,C-EE,P-XE,P-XE-EE, at lower energies, C,R,C-P,P-BS, etc. at higher, just a few to mention, the notations referring to photoelectric, Compton, Rayleigh, electron-escape, characteristic x-ray escape and bremmstrahlung processes. R can be generalized by including inward escapes from dead layers, contact regions, etc. First, R must be convoluted, for the sake of simplicity, with a Gaussian of width $\sigma^2(\vec{r}, E) = \sigma_{el}^2 + \sigma_{stat}^2(E) + \sigma_{coll}^2(\vec{r}, E)$, using conventional notation, then double integrate over the total detector volume in order to obtain the complete detector response function:

$$\frac{N(E_0, E)}{K} = \int\int_V \int_{E'=0}^{\infty} \frac{R(E_0, \vec{r}_0, E', \vec{r})}{\sigma(\vec{r}, E')}$$

$$\exp\left(-\frac{\left[E\,\eta(\vec{r})(1 - B(\vec{r})) - E'\right]^2}{2\sigma^2(\vec{r}, E')}\right) d\vec{r}_0\, d\vec{r}\, dE',$$

where K is a normalization constant. The partial response corresponding to the conventional escape events can be obtained by retaining only the relevant R_{P-XE} term, which can be given as sum of appropriate Lorentzians at $E_0 - E_i$, E_i meaning corresponding X-ray energies, and perhaps accounting for the higher order $R_{P-XE-EE}, R_{P-XE^2}$, etc. distribution functions in the above equation.

[1] G. Kalinka, NIMB 88 (1994) 470

[2] T. Papp, X-ray Spectrom. 32 (2003) 458

7.13 Activities at the Van de Graaff Accelerator Laboratory

L. Bartha

During 2003 the beam time of the VdG-1 machine amounted to 54 hours. The accelerator delivered proton beam used for low energy atomic physics experiments. The beam time of the hollow cathode ion source - which is also operated on the beam transport of VdG-1 accelerator - is excluded.

The 5 MV Van de Graaff machine was operating for 2933 hours during this period. Proton (97.17 %), H_2^+ (3.22 %), D^+ (7.33 %), He^+ (7.85 %) and $^{14}N^+$ (4.42 %) particles were accelerated.

The beam time was distributed among different research subjects as shown in *Table 1.*

The installation of a 4130A Tandetron AMS made by General Ionex Corporation has been started in this year. It will be used in ^{14}C AMS dating in the future. Its beamline heigth has been increased to the heigth of the VdG-5 beamline. This makes easier the connection of the Tandetron beam to the VdG-5 beamlines at any time when it is required.

Table 1. Time distribution among different research activities at VdG-5

Field	**Sign**	**Hours**	**%**
Atomic physics	AP	240	8.18
Nuclear physics	NP	344	11.73
Nuclear astrophysics	NAP	132	4.50
Analytical studies	IBA	2181	74.36
Micromachining	MM	21	0.72
Machine tests	MT	15	0.51
Total		**2933**	**100**

7.14 Status Report on Cyclotron Operation

P. Kovács, I. Szűcs, I. Ander, T. Lakatos, A. Fenyvesi, F. Ditrói, S. Takács, F. Tárkányi

The operation of the cyclotron in 2003 was again concentrated to 9 months; January, July and August were reserved for maintenance, renewal works and holidays. The overall working time of the accelerator was 4051 hours. The breakdown periods amounted to 4 hours last year, the time used for systematic maintenance was 365 hours. The cyclotron was available for users for 3682 hours. The effectively used beam-on-target is summarized in Table 1.

Table 1. Statistics of the irradiation time (beam-on-target) for different research groups

Projects	**Hours**	**%**
Nuclear spectroscopy	568	28.8
Nuclear astrophysics	613	31.0
Radiation tolerance test	50	2.6
Nuclear reaction data	9	0.5
Medical isotope production	617	31.2
Thin layer activation (TLA)	116	5.9
Total	1973	100

In order to improve the circumstances of the irradiations the following renewal and improvements were done:

- Upgrading RF-power supply system of the MGC-20 cyclotron:
  - Final Stages
  - Pre-final Stage
  - Pre-final Stage Rectifier
  - Control Module (with computer control)

  Project was carried out in July and August by the NPK LUTS NIIEFA, St. Petersburg, Russia.
- Removing of limescale from the heat-exchanger of the water-cooling system.
- In order to prevent scaling in the water cooling system a water softening equipment was put into operation in the tap-water circuit.

8.1 Scientific papers, proceedings

1. ALEPH Collaboration., DELPHI Collaboration., L3 Collaboration., OPAL Collaboration., LEPWGHBS Collaboration., Baksay G., Nagy S., Raics P., Szillási Z., Veszprémi V., Zilizi Gy., Dienes B., Horváth D., Trócsányi Z., Ujvári B., et al.: *Search for the standard model Higgs boson at LEP.* Physics Letters B **565** (2003)61.

2. Abbiendi G., Horváth D., Trócsányi Z., Ujvári B., et al.: *Measurement of the mass of the W boson in e+e-collisions using the fully leptonic channel.* European Physical Journal C **26** (2003)321.

3. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., Ujvári B., et al.: *Multi-photon production in e+e- collisions at sqrt(s)=181-209 GeV.* European Physical Journal C **26** (2003)331.

4. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., Ujvári B., et al.: *Search for the Standard Model Higgs boson with the OPAL detector at LEP.* European Physical Journal C **26** (2003)479.

5. Abbiendi G., Horváth D., Trócsányi Z., Ujvári B., et al.: *Decay-mode independent searches for new scalar bosons with the OPAL detector at LEP.* European Physical Journal C **27** (2003)311.

6. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., Ujvári B., et al.: *Charged particle momentum spectra in e+e- annihilation at sqrt(s) = 192-209 GeV.* European Physical Journal C **27** (2003)467.

7. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., Ujvári B., et al.: *Search for a low mass CP-odd Higgs boson in e+e- collisions with the OPAL detector at LEP2.* European Physical Journal C **27** (2003)483.

8. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., Ujvári B., et al.: *Measurement of the cross-section for the process γ-$\gamma \rightarrow$ pp- at sqrt(see) = 183 - 189 GeV at LEP.* European Physical Journal C **28** (2003)45.

9. Abbiendi G., Horváth D., Trócsányi Z., Ujvári B., et al.: *Inclusive analysis of the b quark fragmentation funciton in Z decays at LEP.* European Physical Journal C **29** (2003)463.

10. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., Ujvári B., et al.: *Search for nearly mass-degenerate charginos and neutralinos at LEP.* European Physical Journal C **29** (2003)479.

11. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., Ujvári B., et al.: *A measurement of semileptonic B decays to narrow orbitally-excited charm mesons.* European Physical Journal C **30** (2003)467.

12. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., Ujvári B., Vértesi R., et al.: *Search for pair-produced leptoquarks in e+e- interactions at sqrt(s) 189-209 GeV.* European Physical Journal C **31** (2003)281.

13. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., Ujvári B., Vértesi R., et al.: *Di-jet production in photon-photon collisions at sqrt(see) from 189 to 209 GeV.* European Physical Journal C **31** (2003)307.

14. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., Ujvári B., Vértesi R., et al.: *Measurement of isolated prompt photon production in photon-photon collisions sqrt(see) = 183-209 GeV.* European Physical Journal C **31** (2003)491.

15. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., Ujvári B., et al.: *A measurement of the* $\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$ *branching ratio.* Physics Letters B **551** (2003)35.

16. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., Ujvári B., Vértesi R., et al.: *Bose-Einstein correlations of pi0 pairs from hadronic Z0 decays.* Physics Letters B **559** (2003)131.

17. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., Ujvári B., Vértesi R., et al.: *Test of non-commutative QED in the process e+ e-* $\to \gamma\ \gamma$ *at LEP.* Physics Letters B **568** (2003)181.

18. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., Ujvári B., Vértesi R., et al.: *Search for stable and long-lived massive charged particles in e+e- collisions at sqrt(s) = 130-209 GeV.* Physics Letters B **572** (2003)8.

19. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., Ujvári B., Vértesi R., et al.: *Measurement of heavy quark forward-backward asymmetries and average B mixing using leptons in hadronic Z decays.* Physics Letters B **577** (2003)18.

20. Abbiendi G., Dienes B., Horváth D., Trócsányi Z., Ujvári B., Vértesi R., et al.: *Search for the single production of doubly-charged Higgs bosons and constraints on their couplings from Bhabha scattering.* Physics Letters B **577** (2003)93.

21. Achard P., Baksay G., Nagy S., Raics P., Szillási Z., Tarján P., Veszprémi V., et al.: *Inclusive charged hadron production in two-photon collisions at LEP.* Physics Letters B **554** (2003)105.

22. Achard P., Baksay G., Nagy S., Raics P., Szillási Z., Tarján P., Veszprémi V., et al.: *Measurement of W polarisation at LEP.* Physics Letters B **557** (2003)147.

23. Achard P., Baksay G., Nagy S., Raics P., Szilassi Z., Tarján P., Veszprémi V., et al.: *Study of the e+e-* $\to$ *Ze+e- process at LEP.* Physics Letters B **561** (2003)73.

24. Achard P., Baksay G., Nagy S., Raics P., Szillási Z., Tarján P., Veszprémi V., et al.: *Search for colour reconnection effects in e+e-* $\to$ *W+W-* $\to$ *hadrons through particle-flow studies at LEP.* Physics Letters B **561** (2003)202.

25. Achard P., Baksay G., Nagy S., Raics P., Szillási Z., Tarján P., Veszprémi V., et al.: *Measurement of exclusive p0p0 production in two-photon collisions at high Q2 at LEP.* Physics Letters B **568** (2003)11.

26. Achard P., Baksay G., Nagy S., Raics P., Szillási Z., Tarján P., Veszprémi V., et al.: *Search for excited leptons at LEP.* Physics Letters B **568** (2003)23.

27. Achard P., Baksay G., Nagy S., Raics P., Szillási Z., Tarján P., Veszprémi V., et al.: *Search for a Higgs boson decaying to weak boson pairs at LEP.* Physics Letters B **568** (2003)191.

28. Achard P., Baksay G., Nagy S., Raics P., Szillási Z., Tarján P., Veszprémi V., et al.: *Proton-antiproton pair production in two-photon collisions at LEP.* Physics Letters B **571** (2003)11.

29. Achard P., Baksay G., Nagy S., Raics P., Szillási Z., Tarján P., Veszprémi V., et al.: *Z boson pair-production at LEP.* Physics Letters B **572** (2003)133.

30. Achard P., Baksay G., Nagy S., Raics P., Szillási Z., Tarján P., Veszprémi V., et al.: *Search for charged Higgs bosons at LEP.* Physics Letters B **575** (2003)208.

31. Achard P., Baksay G., Nagy S., Raics P., Szilassi Z., Tarján P., Veszprémi V., et al.: *Search for doubly-charged Higgs bosons at LEP.* Physics Letters B **576** (2003)18.

32. Achard P., Baksay G., Nagy S., Raics P., Szilassi Z., Tarján P., Veszprémi V., et al.: *Measurement of charged-particle multiplicity distributions and their Hq moments in hadronic Z decays at LEP.* Physics Letters B **577** (2003)109.

33. Afanasiev S. V., Gál J., Molnár J., et al.: *Bose-Einstein correlations of charged kaons in central Pb+Pb collisions at E beam = 158 GeV per nucleon.* Physics Letters B **557** (2003)157.

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8.8 Other abstract, poster, talk

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493. Rajta I.: *Research activities at the Department of Electrostatic Accelerators of Atomki, Debrecen, Hungary.* University of Vienna. Vienna, Austria, May 28, 2003.

494. Simon A.: *The new Surrey nuclear microprobe.* Advanced Technology Institute, University of Surrey, Guildford, UK, April 10, 2003.

495. Somorjai E., Fülöp Zs., Gyürky Gy.: *Experimental study of astrophysical p-process.* National Laboratory in Gran Sasso. Gran Sasso, Italy, 5 June, 2003.

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498. Szelecsényi F.: *Estimation of production yields based on measured cross-section data.* Lecture Hall, Theragenics Corporation. Buford, G.A., USA, 17 April, 2003.

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500. Tőkési K.: *Hollow atoms in microcapillaries.* Department of Matrial and Life Science. Graduate School of Engineering. Osaka University Suita, Osaka, Japan, 12 March, 2003.

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8.9 Hebdomadal Seminars

1. February 7 *Shell model at the drip lines* Takaharu Otsuka (Tokyo University)
2. February 27 *Plasma diagnostic research on ECR-ion source* L. Kenéz (Kolozsvár)
3. March 6 *Systematic analysis of neutron-rich carbon isotopes* G. Thiamova (University of Tokyo)
4. March 11 *State of affairs* M. Pálinkás, R. Lovas
5. 3 April *Introduction of new colleagues in ATOMKI*
6. April 17 *Physics in common knowledge* Gy. Radnai (ELTE, Budapest)
7. April 24 *Report on the plans of NUPECC* A. Krasznahorkay
8. May 22 *Renormalization group method (from quantum field theory to superconductivity)* I. Nándori (University of Debrecen)
9. May 29 *Superfluid He-3, particle physics, and the big bang* D. Vollhardt (University of Augsburg)
10. September 25 *Pushing the physical limits of optical lithography* J. H. Burnett (NIST)
11. September 30 *Study of collective and single particle states near the proton instability line* D. Sohler
12. October 2 *Study of neutron skin thickness and deformation of nuclei* M. Csatlós
13. October 3 *Femtosecond lasers and their applications* K. Osvay (University of Szeged)
14. October 9 *Possibilities and perspectives in X-ray micro analitics based on synchrotron radiation excitation* A. Somogyi (ESRF, Grenoble)
15. October 16 *Micro-PIXE and micro-SRXRF study of impact materials collected at the Barringer crater* I. Uzonyi
16. October 29 *Perspectives of generation of ordered light at short wave lengths* S. Szatmári (University of Szeged)
17. November 19 *Enhancement of d+d fusion in deuterised Pd* P. Kálmán and T. Keszthelyi (BME, Budapest)
18. November 27 *The new Surrey nuclear microprobe* A. Simon
19. December 4 *Applications of inverse scattering methods to nuclear physics* R. S. Mackintosh (The Open University Milton Keynes, UK)
20. December 11 *Mini-workshop on antimatter and CPT-symmetry* Makoto Fujiwara (RIKEN) - ATHENA, Cody Storry (Harvard) - ATRAP, Masaki Hori (Tokyo/CERN) - ASACUSA
21. December 15 *The theory of K-alpha generation in femtosecond laser-produced plasmas* D. Salzmann (Soreq NRC, Department of Plasma Physics, Israel)

Author index

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