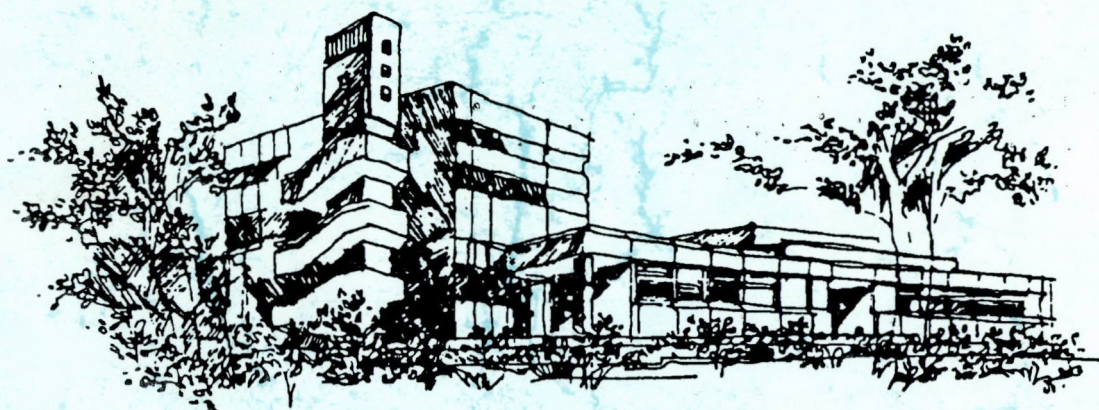


ATOMKI

ANNUAL REPORT

1999



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



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H-4001 Debrecen
Hungary

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G. Hock

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Preface

The “consolidation” years of the research institutes of the Hungarian Academy of Sciences ended with 1999. By 1999 we only sensed the blessings of the consolidation. Yet even this year, we had to reduce the staff by 3%, as a result of a “scheduled” economy measure, imposed by the government, that concerns almost all of the public sector. (At present we already know that we have to reduce the staff by another 3% in 2000 and 2% in 2001 as well as in 2002.) The financial and personnel conditions at the end of 1999 are given in the pie diagrams to follow this Preface.

For ATOMKI 1999 was a year of conferences, retrospective and forward-looking events and their combinations.

With the support of UNESCO and EPS, in March we held a workshop on *The Future of Physics and Society*. This meeting was the first preparatory meeting for the first World Conference on Science held in Budapest in June, 1999. Its main objective was to give an overview of how physics research and the physicists face the challenges of our age. We surveyed the conditions for doing physics research at the turn of the millennium. We took stock of what physics can do for society, for a better future of mankind, and we pointed out some world problems that cannot be solved without the participation of physicists. The meeting covered the following topics: (i) appreciation of physics/science in society, (ii) the future of physics/science as part of human culture and as key to the prosperity/survival of mankind; (iii) physics education in an era of disillusionment and (iv) the status of physics research and education in Central and Eastern Europe. The written forms of some of the talks can be read in the virtual “Proceedings” at the ATOMKI web-site, (<http://www.atomki.hu/future/proceedings.html>), including the summary talk by R.S. Mackintosh (Open University, Milton Keynes), which contains important messages addressed to the World Conference and to the physics community.

The *The Future of Physics and Society* conference was scheduled to coincide with the yearly “festivity” of physics in Debrecen, the Physics Week, whose subject was also the future of physics. Some Hungarian speaking participants played a double role: addressed the meeting of physicists and, in a popular lecture, they addressed the general public as well. In addition, physics students were invited by the initiator of the *Future* conference, Prof. Herwig Schopper (CERN), for an evening chat.

Part of another satellite meeting of the World Conference was also held in Debrecen. That meeting, organized by Prof. G. Marx, Budapest, was also related to the future; its title was *The Future of the Universe and the Future of our Civilization*.

In April we held an international workshop entitled *X-Ray Photoelectron Spectroscopy: from Physics to Data* at the *puszta* (i.e., empty, barren land) of Hortobágy, sponsored by the International Union for Vacuum Science, Technique and Applications. The esoteric surroundings included a luxury hotel. This meeting was organized by the Section of Electron Spectroscopy of ATOMKI. Early in autumn we had the *5th International Conference on Rare Gas Geochemistry* at the much less exotic

site of the Debrecen Centre of the Academy of Sciences. It was organized by the radon group of the Section of Environmental and Earth Sciences of ATOMKI.

We commemorated the 90th anniversary of the birth of our founder, Prof. Alexander Szalay in October. He was director of ATOMKI up to 1975 and an active member up to his death in 1987. He started his career in the thirties with pure nuclear physics, and the focus of his interest was later shifted to interdisciplinary fields: nuclear geochemistry and trace element research. He was a professor of the Debrecen University between 1939 and 1967, founded ATOMKI in 1954 and was elected an ordinary Member of the Hungarian Academy of Sciences. A memorial address was given by Prof. István Lovas, who is a prominent pupil who left the orbit around Szalay very early. In his commemoration he showed up the perspective of a close as well as of a remote observer.

The first post-war generation of the Szalay school is now about seventy. In 1998 we commemorated the seventieth birthdays of Prof. Dénes Berényi and Dr. István Berecz. In May 1999 we held an informal celebration for Prof. Tibor Fényes.

I should also mention that there were an excessive number of funerals last year. Among them there was one which ought to be mentioned here explicitly: Dr. Ede Hertelendi, Head of the Section of Environmental and Earth Sciences died in a car accident on 3rd September. He was not only a most prominent but also a most important colleague of ours. In 1998 he was duly awarded the prestigious Dénes Gábor Prize for innovative activity in scientific and technological fields. His group has been doing environmental research ranging from paleoclimatology through hydrology and nuclear energetics and also radiocarbon dating for archeology. He died just at the moment when he won two major project tenders for the Institute. The subjects of these projects are two aspects of the environmental safety assessment of the nuclear waste depository at Püspökszilágy. It has been extremely painful to lose Ede, and it is a very tough job to carry on his heritage. His successor heading the group of the laboratory for environmental analysis is Dr. A. Zsuzsanna Szántó. The Section of Environmental and Earth Sciences, which is the organizational unit, to which this laboratory belongs, is now headed by Dr. Sándor Mészáros, who is serving on as head of the cryogenic laboratory and as deputy director as well.

The above two projects are the largest in volume among the applied science projects that are going on. The completion of the chemistry unit for the production of ^{123}I made for Egypt has been somewhat delayed.

After some years of no award from the Eötvös Physical Society, last year three of our colleagues were awarded: Dr. András Kruppa (Budó Prize), Dr. Géza Lévai (Jánossy Prize) and Dr. János Végh (Szalay Prize). It is also to be mentioned that Dr. Ádám Kovách, scientific secretary of the Institute, has been elected Secretary General of the Eötvös Society. The Szalay Prize of this Institute for research in basic science was won by Dr. Ákos Kövér for his works ion-atom and positron-atom collisions.

Last year was the year of the completion of the merger of the Debrecen universities into the University of Debrecen. The new (or re-born) single university has come to existence on 1st January, 2000. ATOMKI held an associate status with the former universities, and the representatives of the Institute took part in the process

of the unification throughout. A similar association treaty with the new University will be subject of the next Annual Report.

It is always very difficult to single out one or two out of a copious number of significant results like those contained in this Annual Report. This time I mention two recent results of atomic physics.

It is well known that the spectrum of electrons ejected at forward angles from ion-atom collisions shows a cusp at relative velocities equal to the orbital velocity of the target atom. This phenomenon is explained as an electron capture into the continuum of the projectile. Some years ago it caused a great surprise that, in an experiment in ATOMKI, a cusp was observed in the collision of two neutral atoms, which cannot be explained as an electron capture into the continuum. Last year theoretical calculations indicated that a cusp should be observable if the projectile atom shows dipolar behaviour. Since for the projectile used in this experiment that is possible only when it is in certain excited states, this cusp may arise from collisions involving an atomic projectile in an excited state, which is an intriguing possibility [L. Sarkadi *et al.*, p. 26].

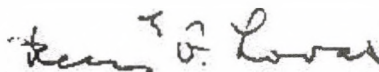
In recent years multiple scattering effects in atomic collisions have attracted considerable attention worldwide as well as in ATOMKI. Electron peaks attributable to ping-pong like double scattering of electrons between the target and the projectile were observed elsewhere. Last year evidence for projectile-target-projectile triple scattering was found in an experiment performed in ATOMKI [B. Sulik *et al.*, p. 28].

I have to announce here that my appointment to the post of the Director of this Institute has been prolonged by five years, ending in December, 2004.

To finish with, I should mention that last year a profile of ATOMKI appeared in Nuclear Physics News International Vol. 4, No. 4, on pp. 21-27. This article is also accessible at the web (<http://www.atomki.hu/atomki/PoAtomki/PoAtomki.html>). In accord with the readership of Nuclear Physics News, this article covers the activity of ATOMKI in the field of nuclear physics primarily.

This Annual Report has been prepared on the basis of \LaTeX , and will be available at the web-site <http://www.atomki.hu> in HTML, DVI, PDF and PS(.GZ) formats.

Debrecen, 28 May 2000



Rezső G. Lovas
Director

Organizational structure of ATOMKI

DIRECTOR: Prof. R.G. Lovas

DEPUTY DIRECTORS:

Prof. Á.Z. Kiss
Dr. S. Mészáros

FINANCE OFFICER:

Dr. M. Pálinkás

SECRETARIAT

Scientific secretary: Dr. Á. Kovách

INFORMATION SERVICES

Chief librarian: Mrs. M. Nagy

ACCOUNTING

headed by Mrs. J. Sass

BASIC SERVICES
& MAINTENANCE

headed by I. Katona

SCIENTIFIC SECTIONS

DIVISION OF NUCLEAR PHYSICS

headed by Prof. J. Cseh

SECTION OF NUCLEAR SPECTROSCOPY

headed by Dr. A. Krasznahorkay

SECTION OF

ELECTROSTATIC ACCELERATORS

headed by Dr. E. Somorjai

SECTION OF THEORETICAL PHYSICS

headed by Dr. T. Vertse

DIVISION OF ATOMIC PHYSICS

headed by Prof. J. Pálinkás

SECTION OF ATOMIC COLLISIONS

headed by Dr. L. Sarkadi

SECTION OF ELECTRON SPECTROSCOPY

headed by Dr. D. Varga

CYCLOTRON SECTION

headed by Dr. F. Tárkányi

SECTION OF ENVIRONMENTAL
& EARTH SCIENCES

headed by Dr. S. Mészáros

SECTION OF ELECTRONICS

headed by Dr. J. Gál

MECHANICAL WORKSHOP

headed by Ing. I. Gál

Data on ATOMKI

Personnel

At present the Institute employs 192 persons. The affiliation of personnel to units of organization and the composition of personnel are given below.

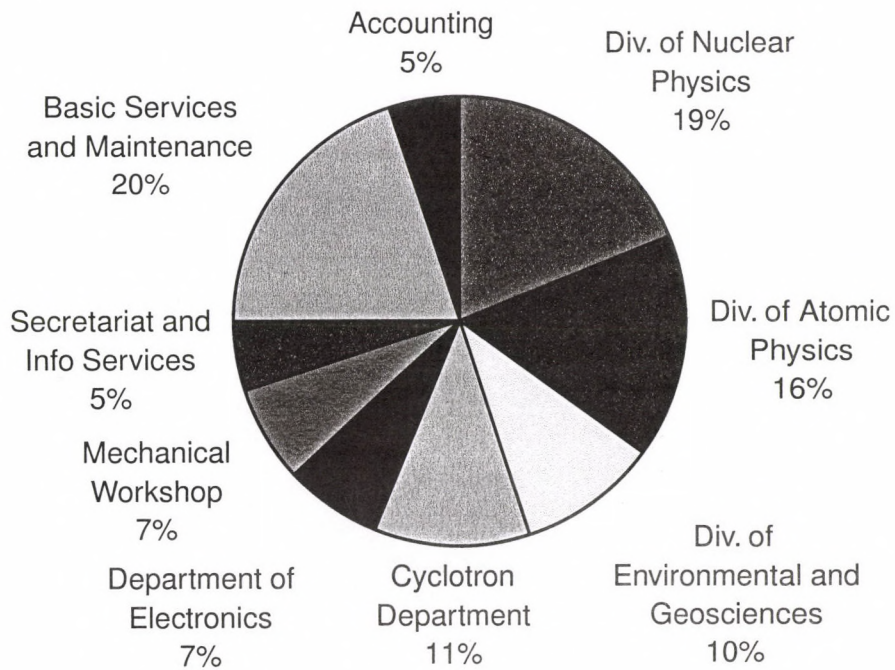


Fig. 1: Affiliation of personnel to units of organization

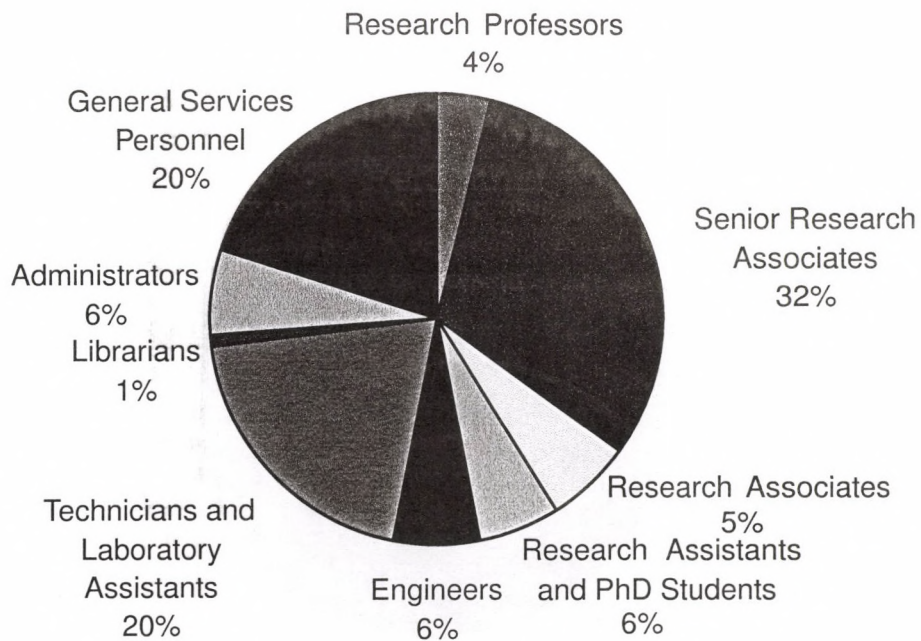


Fig. 2: Composition of personnel

Finance

In 1999 the total budget of the Institute was 675 million Hungarian forints. The composition of the budget and the share of personnel expenditure within the budget are shown below.

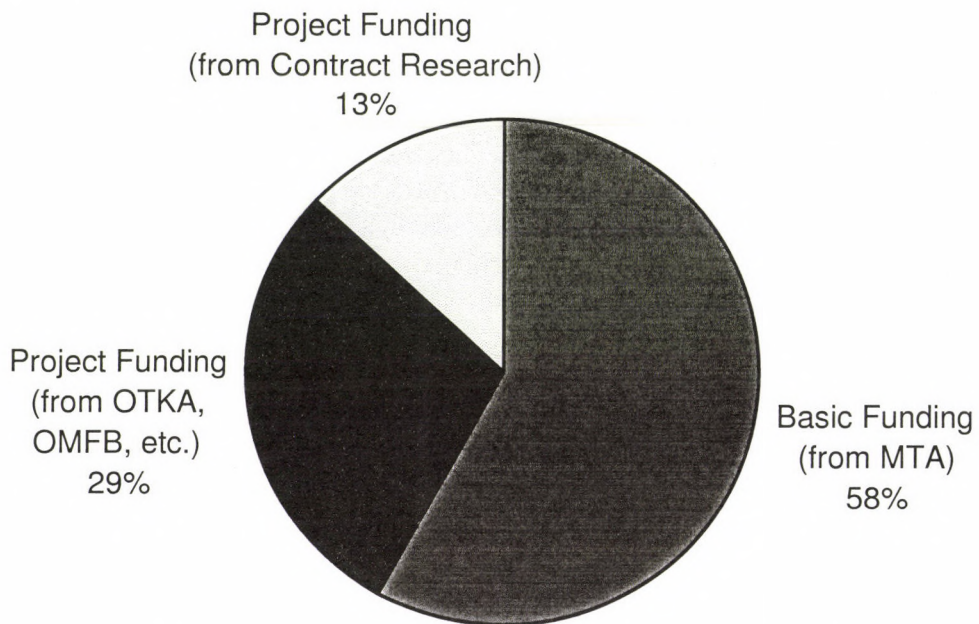


Fig. 3: Composition of the budget of the Institute
MTA: Hungarian Academy of Sciences
OTKA: National Fund for Scientific Research
OMFB: National Committee for Technological Development

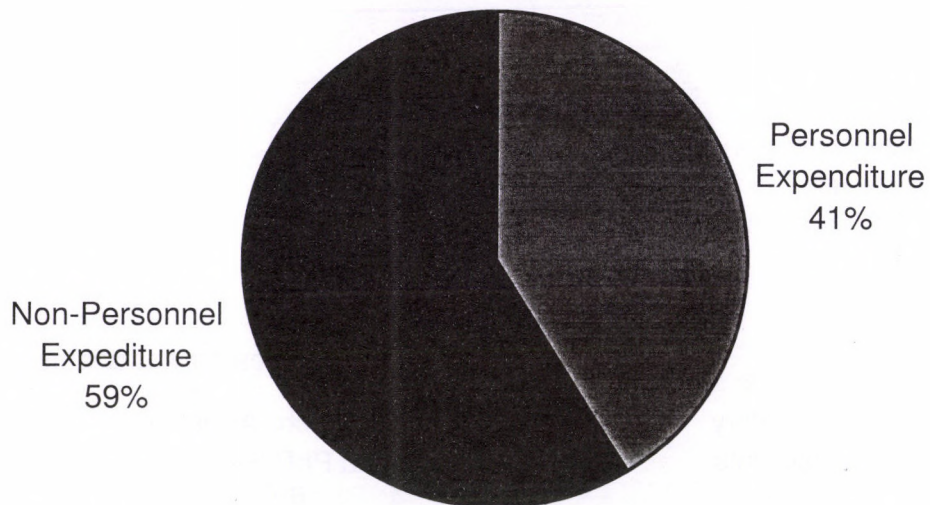


Fig. 4: Breakdown of expenditure into personnel and non-personnel expenditures

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Break-up of Dipolar Rings under an External Magnetic Field

F. Kun,[†] K.F. Pál, W. Wen[‡] and K.N. Tu[‡]

[†] Department of Theoretical Physics, University of Debrecen

[‡] Department of Materials Science, University of California Los Angeles (UCLA)

Magnetorheological (MR) fluids are generally composed of micrometer sized magnetic particles suspended in a non-magnetic viscous liquid. In the absence of an external magnetic field the particles with permanent magnetic moment aggregate due to the interplay of the dipole–dipole interaction and of the Brownian motion of the particles, and build up complex structures. Recently, we reported an experimental and theoretical investigation of the formation of regularly shaped rings of dipoles in MR fluids in the absence of an external magnetic field, and that of the competition of rings with randomly oriented open chains and labyrinthine structures when changing the volume fraction of particles [1].

In the present work an experimental and theoretical study of the deformation and break-up process of rings, formed by magnetization-controllable microspheres, under the application of an external magnetic field was performed. When the external magnetic field is applied parallel to the plane of the rings, we found that the break-up process has three different outcomes depending on the way of application and time history of the external field: *a*) deformation into a compact set of dipoles with a triangular lattice structure *b*) opening into a single chain, and *c*) break-up into two chains with various relative sizes. Computer simulations of the break-up process have been carried out, taking into account solely the dipole–dipole and dipole–external field interactions, without thermal noise. The good agreement between the experimental results and the simulations for cases *b*) and *c*) is illustrated by Fig. 1 [2].

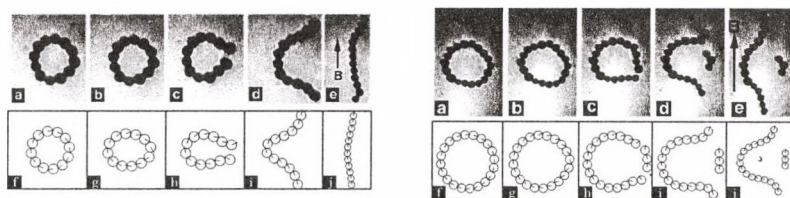


Fig. 1: See text

[1] W. Wen, F. Kun, K.F. Pál, D.W. Zheng and K.N. Tu, *Phys. Rev. E* **59** (1999) R4758.

[2] F. Kun, K.F. Pál, W. Wen and K.N. Tu, submitted to *Phys. Rev. Lett.*

Conditionally Exactly Solvable Potentials and Supersymmetric Transformations

G. Lévai and P. Roy[†]

[†] Physics and Applied Mathematics Unit, Indian Statistical Institute
Calcutta, India

A recent development in quantum mechanics was the introduction of conditionally exactly solvable (CES) potentials. These potentials are solvable only if some of their parameters are set to specific values. A large class of CES potentials was constructed as supersymmetric (SUSY) partners of some simple potentials [1].

Taking advantage of earlier results, we used a systematic method to construct SUSY partners of a potential and applied it to the harmonic oscillator problem [2]:

$$\tilde{V}_{\text{HO}}(r) = V_{\text{HO}}(r) - \frac{d^2}{dr^2} \ln \phi(r) \equiv \frac{1}{2}r^2 + \frac{\gamma(\gamma+1)}{2r^2} + \gamma + \frac{3}{2} - \frac{d^2}{dr^2} \ln \phi(r).$$

Here $\phi(r)$ is the solution (physical or unphysical) of the original $V_{\text{HO}}(r)$ potential. In its general form $\phi(r)$ is the linear combination of two confluent hypergeometric functions, and it has to be nodeless to avoid singularities in $\tilde{V}_{\text{HO}}(r)$. Depending on the $r \rightarrow 0$ and $r \rightarrow \infty$ boundary conditions for $\phi(r)$ (i.e. whether it is convergent or divergent there), four types of SUSY transformations can be formulated.

When $\phi(r)$ is convergent in both limits (transformation T_1), it can only be the ground-state solution at $E = 0$, and we get the usual SUSYQM transformation eliminating the ground state of $V_{\text{HO}}(r)$. When $\phi(r)$ is divergent in one of the limits, the T_3 and T_4 transformations arise, which leave the spectrum intact, only change formally the orbital angular momentum γ . Finally, when $\phi(r)$ is divergent in both limits, we get the T_2 transformation which introduces a new ground state in $\tilde{V}_{\text{HO}}(r)$ below the ground state of $V_{\text{HO}}(r)$ and also decreases γ formally by one unit.

$\phi(r)$ contains a single $F(a, b; z)$ function in the T_1 and T_3 cases, while it is a linear combination of two such functions for T_4 and T_2 . Restricting these also to a single term and setting $a = -N$, $\phi(r)$ turns into a polynomial. For $N = 0$, $\tilde{V}_{\text{HO}}(r)$ becomes a new harmonic oscillator potential. For $N = 1$ its typical form is

$$\tilde{V}_{\text{HO}}(r) = \frac{1}{2}r^2 + \frac{\tilde{\gamma}(\tilde{\gamma}+1)}{2r^2} + C(\gamma) + \frac{4g_1^2(\gamma)r^2}{(1+g_1(\gamma)r^2)^2} - \frac{2g_1(\gamma)}{1+g_1(\gamma)r^2}$$

with $\tilde{\gamma} = \gamma \pm 1$, while $C(\gamma)$ and $g_1(\gamma)$ are constants, depending on the case (T_2 , T_3 or T_4) considered. Of these, the T_3 case has been discussed previously [1]. For $N > 1$ more complicated, but closed formulas can be obtained for $\tilde{V}_{\text{HO}}(r)$.

The whole procedure can be repeated for any solvable potential, including also one-dimensional problems with different boundary conditions for $\phi(r)$.

- [1] G. Junker and P. Roy, *Ann. Phys. (N.Y.)* **270** (1998) 155.
[2] G. Lévai and P. Roy, *Phys. Lett. A* **264** (1999) 117.

Unified Description of Bound, Resonant and Scattering States

B. Kónya, G. Lévai and Z. Papp

Recently we have introduced a general method for calculating the discrete Hilbert-space basis representation of the Green's operators of those Hamiltonians which have infinite symmetric tridiagonal matrix forms [1]. The elements of this matrix are used in the calculation of the Green's matrix in terms of a three-term recurrence relation and continued fractions. We specified our general approach to the case of the Coulomb problem and the Coulomb-Sturmian basis associated with it [1].

As a further step, we can combine this new way of calculating the Coulomb-Green's matrix with a technique of solving integral equations in discrete Hilbert-space-basis representations [2]. This provides us with a quantum mechanical approximation method which is rather general in the sense that it is equally applicable to solving bound-, resonant- and scattering-state problems with practically any potential of physical relevance. The method is especially suited to problems where Coulomb-like asymptotics have to be treated, but the formalism also contains the case of the free Green's operator as a special case.

One often encounters similar problems in nuclear physics, where one typically deals with objects interacting by a "strong" potential at short distances and by the Coulomb force at large distances. As a natural playground to demonstrate the abilities of our approach, we chose the interaction of two α particles. This system is rather well-studied and it has characteristic resonances, some of which would turn into bound states in the absence of the Coulomb interaction, furthermore, the scattering phase shifts also show interesting features in the various angular momentum channels. We considered the following interaction of the two α particles:

$$V_{\alpha-\alpha}(r) = A \exp(-\beta r^2) + \frac{Z^2 e^2}{r} \operatorname{erf}(\gamma r) ,$$

where $\operatorname{erf}(z)$ is the error function. In order to locate the energies of the bound and the resonant states, we had to find the poles of the determinant of the Green's matrix $\underline{G}_l(z) = [(\underline{G}_l^C(z))^{-1} - \underline{V}_l]^{-1}$, where $\underline{G}_l^C(z)$ is the Coulomb Green's matrix and \underline{V}_l is the matrix of $V_{\alpha-\alpha}(r) - Z^2 e^2/r$ expanded on a basis of size N . These energies converged reasonably fast: bases of $N = 40$ were sufficient to reach convergence in all cases. We also determined the scattering phase shifts $\delta_l(E)$ for $l = 0, 2$ and 4 .

In conclusion, our method proved to be an effective way of describing bound, resonant and scattering states on an equal footing, while these states are usually discussed in rather different ways in conventional quantum mechanical approaches. Besides the example presented above, our method can readily be applied to a wide variety of realistic interactions used in nuclear physics and elsewhere.

[1] B. Kónya, G. Lévai and Z. Papp, *J. Math. Phys.* **38** (1997) 4832.

[2] B. Kónya, G. Lévai and Z. Papp, *Phys. Rev. C*, in press (nucl-th/9908018).

Stability of Small Exotic Molecules

J.Zs. Mezei, K. Varga[†] and R.G. Lovas

[†] Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA

Three and four unit-charge particles with different masses may form bound states depending on the mass ratios, e.g. $\text{Ps}^- = (e^-, e^+, e^-)$ with mass ratio $\sigma = m_{e^+}/m_{e^-} = 1$, $\text{H}^- = (p, e^-, e^-)$ with $\sigma = m_{e^+}/m_p \cong 0$ and $\text{Ps}_2 = (e^+, e^+, e^-, e^-)$, $\text{HPs} = (p, e^-, e^+, e^-)$ and $\text{H}_2 = (p, p, e^-, e^-)$.

The aim of this work is to find out how many particles of unit charges can be put together to form bound states. We explore the possibility of the formation of stable $N = 5, 6, \dots$ -particle systems of unit charges. We use a variational approach, in which the trial function is constructed out of generalised Gaussians whose parameters are determined by stochastic sampling. For few-body bound states this method has been shown to produce accurate results [1, 2].

First we made calculations for the five-body system $(m^+, m^-, m^+, m^-, M^+)$ with $0 \leq \sigma \leq \infty$, where $\sigma = m/M$. We found that the binding energy of the system is larger than the nearest threshold for $0 \leq \sigma \leq 1.81$, so the system in this region of mass ratio is bound.

In the case of the system $(m^+, m^-, m^-, M^+, M^+)$ we cannot find a bound state for $\sigma = 0$. For $1 \leq \sigma \leq \infty$, however, the system is bound. By decreasing σ from $\sigma = 1$, the binding energy is reduced, and around $\sigma = 0.4$ the system dissociates into (m^-, m^-, M^+, M^+) plus m^+ .

Some six-body systems are under study, and cases have been found both for the existence and non-existence of bound states.

From this study we can learn, e.g. that an H_2 molecule cannot bind a positron and the positronium molecule can bind a proton, but it cannot bind an electron, unless we make the extra electron non-identical with the others. By comparing systems formed by identical and non-identical particles, we can point out the role of the Pauli principle in reducing the binding energy.

[1] Y. Suzuki and K. Varga, *Stochastic Variational Approach to Quantum-Mechanical Few-Body Problems*, Springer-Verlag, 1998.

[2] K. Varga, *Phys. Rev. Lett.* in press.

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Measurement of the ${}^7\text{Be}(p,\gamma){}^8\text{B}$ Reaction with Solid State Targets

F. Strieder,[†] Gy. Gyürky, E. Somorjai and the LUNA Collaboration

[†] Institut für Physik mit Ionenstrahlen, Ruhr-Universität Bochum, Germany

The absolute cross section $\sigma_{17}(E)$ of the ${}^7\text{Be}(p,\gamma){}^8\text{B}$ reaction influences sensitively the calculated flux of high-energy neutrinos from the sun. Due to its importance for the solar-neutrino-puzzle, the cross section $\sigma_{17}(E)$ should be known with adequate precision, i.e. to better than 5% [1]. In order to reach this goal a new measurement of $\sigma_{17}(E)$ was performed at the Dynamitron Tandem Laboratorium in Bochum. This experiment includes for the first time measurements with Pt and Cu backings taking into consideration the possible influence of the recoil loss effect [2]. The ${}^7\text{Be}$ nuclides were produced in a metallic Li sample via the ${}^7\text{Li}(p,n){}^7\text{Be}$ reaction using a 11.4 MeV proton beam ($20\mu\text{A}$) from the cyclotron of the ATOMKI. Using hot chemistry the activated samples were transformed into nearly pure ${}^7\text{Be}$. The 4 MV Dynamitron tandem accelerator at the Ruhr-Universität Bochum provided a proton beam at $E_p = 0.3$ to 3 MeV with a maximum current in the range of 10 μA . The cross section was determined from the yield of the ${}^8\text{B}$ recoils, which

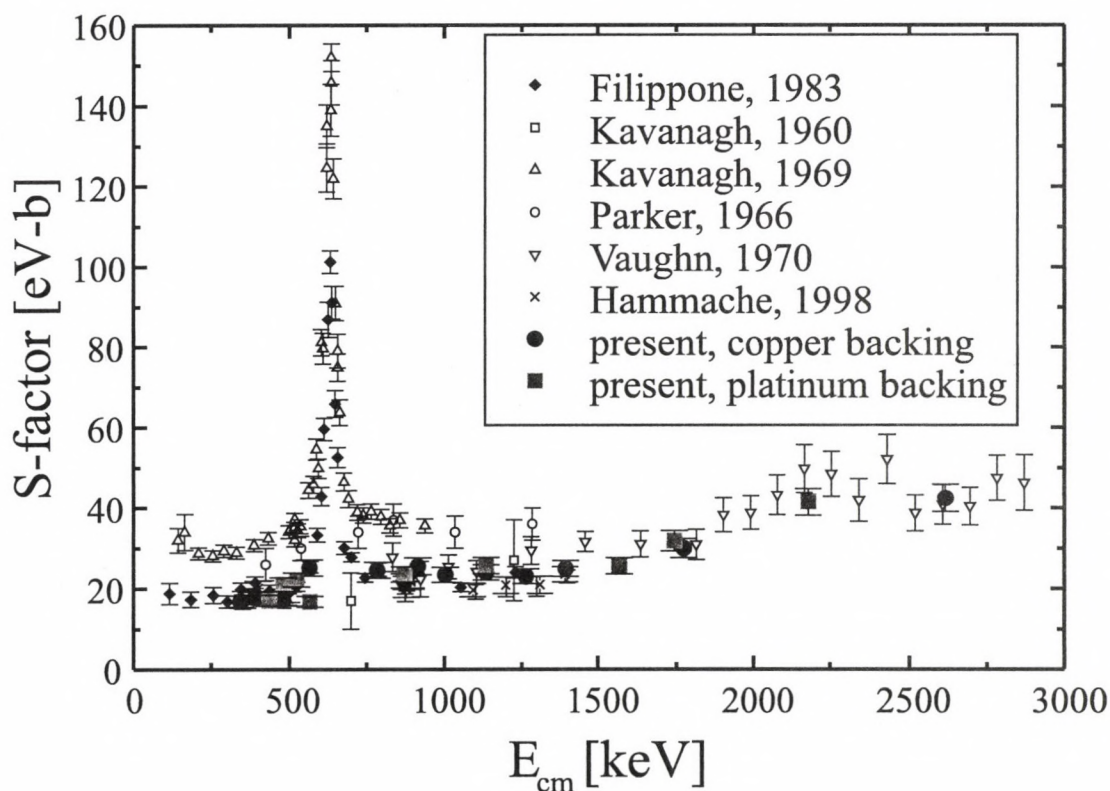


Fig. 1: See text

was deduced from the β -delayed α -decay of ${}^8\text{B}$ ($T_{1/2} = 770$ ms). The target was mounted on a rotating wheel, which moved the target between the beam irradiation position and the ${}^8\text{B}$ -decay counting position (Si detector). The detector efficiency, the irradiation/counting-, and the transfer time-intervals were determined using a calibrated α -source mounted in the target position. The beam current was measured in a Faraday cup mounted behind the target. The number of ${}^7\text{Be}$ target nuclei was determined by measuring the γ -activity of the target. The measurements were carried out for targets both on Pt and Cu backing. Preliminary results (see Fig. 1) are in good agreement with the measurement of Filippone et al. [3] and suggest that within the experimental errors there is no influence of the recoil loss effect.

- [1] J.N. Bahcall and M.H. Pinsonneault, *Rev. Mod. Phys.* **64** (1992) 885.
- [2] F. Strieder, et al., *Eur. Phys. J.* **A3** (1998) 1.
- [3] B. W. Filippone, et al., *Phys. Rev.* **C28** (1983) 2222.

Absolute Cross Section of $p(^7\text{Be},\gamma)^8\text{B}$ Using a Noval Approach

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The absolute cross section $\sigma(E)$ of the $^7\text{Be}(p,\gamma)^8\text{B}$ reaction influences sensitively the calculated flux of high-energy neutrinos from the sun, where the reaction takes place at the Gamow energy $E_0 = 18$ keV. Due to its importance for the solar-neutrino-puzzle, the $\sigma(E)$ should be known to better than 5% [1]. As the cross section dropses nearly exponentially at sub-Coulomb energies, $\sigma(E)$ could not be measured yet at E_0 . Instead, $\sigma(E)$ was determined at higher energies and extrapolated to E_0 . Experiments have been performed using radioactive ^7Be both as solid target [2] and beam [3]. The reported $\sigma(E)$ data — covering the energy range $E_{\text{cm}} = E = 0.12$ to 8.75 MeV — show however a considerable scatter, both in absolute values and to some extent also in their energy dependences.

At the 3 MV tandem in Naples we remeasured the absolute cross section $\sigma(E)$ of $^7\text{Be}(p,\gamma)^8\text{B}$ at $E = 994$ keV using a ^7Be radioactive ion beam, a windowless H_2 gas target system and a recoil mass separator consisting of momentum and velocity filters and a ΔE - E detector telescope. Details of the experimental setup have been published [3] and shown in Fig. 1. The ^7Be nuclides were produced in a metallic Li sample via the $^7\text{Li}(p,n)^7\text{Be}$ reaction using the proton beam (11.4 MeV; 20 μA) of the cyclotron in Debrecen. Using hot chemistry the activated sample were transformed into nearly pure ^7Be pills to be used as cathodes in the sputter ion source of the Naples tandem. Using a post-stripper foil, a Wien-filter and the analysing magnet high cleanliness of the resulting $^7\text{Be}^{4+}$ beam ($E_{\text{Be}} = 8$ MeV; $I_{\text{max}} \approx 20$ ppA) has been achieved. The pressure of the H_2 gas target was $p = 5$ mbar. A pilot $^7\text{Li}^{3+}$ beam was used for the tuning of the recoil separator. The number of ^8B recoils of $p(^7\text{Be},\gamma)^8\text{B}$ measured in the telescope was compared to the concurrently observed $^7\text{Be} + p$ elastic scattering yield. The energy $E = 994$ keV is far below the Coulomb barrier, $E/EC = 0.73$, suggesting the validity of the Rutherford scattering law, however, interference effects with the broad resonance at $E_R = 632$ keV could lead to some deviations from it at $E = 994$ keV; a measurement of these possible deviations is in progress.

With this novel approach, the ${}^8\text{B}$ yield (13 ± 4 events) leads to the absolute cross section $\sigma(E) = 0.40 \pm 0.15 \mu\text{b}$ of $p({}^7\text{Be}, \gamma){}^8\text{B}$ at $E = 994$ keV corresponding to $S(0) = 13 \pm 5$ eV b. The result is consistent with the values recommended recently.

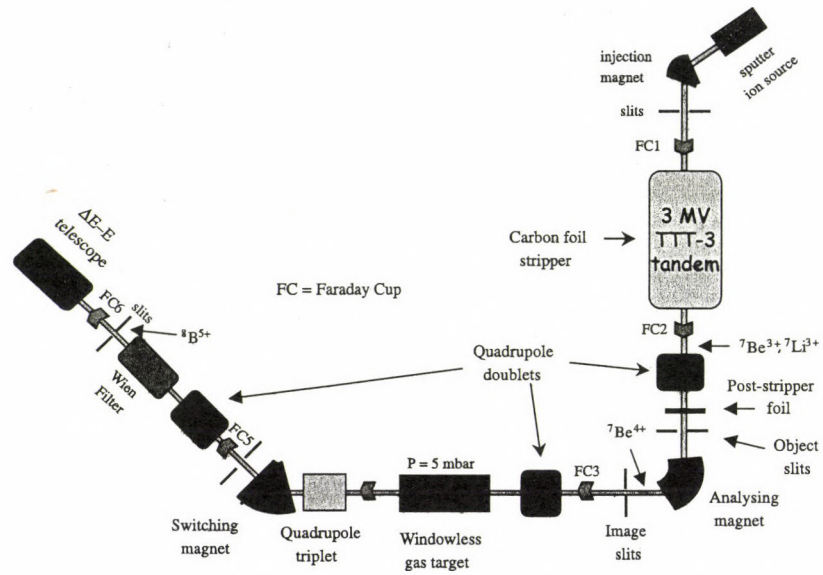


Fig. 1: Schematic view of the experimental setup for the $p({}^7\text{Be}, \gamma){}^8\text{B}$ measurement

- [1] J.N. Bahcall and M.H. Pinsonneault, *Rev. Mod. Phys.* **64** (1992) 885.
- [2] F. Hammache et al., *Phys. Rev. Lett.* **80** (1998) 928 and references therein.
- [3] L. Campajola et al., *Z. Phys.* **A356** (1996) 107 and references therein.

Coulomb Dissociation of Unstable Nuclei

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The determination of cross sections of radiative capture reactions is of primary importance to nuclear astrophysics network calculations. However, the extremely low expected yields at stellar temperatures make this task very complicated and the reduction of systematic errors demands various experimental solutions.

The Coulomb excitation to continuum states i.e. the Coulomb dissociation method is a powerful alternative to the direct radiative capture measurements. Here, the photodisintegration rate of the residual nucleus (in the radiative capture reaction) is determined from the yield of dissociation in the virtual photon field of a heavy nucleus. In turn, the photodisintegration rate can be associated with the radiative capture rate in question [1]. The available energy range (10–100 MeV·A) and intensity (10^3 – 10^5 /s) of radioactive beams allow also to study reactions involving unstable nuclei [2].

In a series of experiments in RIKEN, we have studied the $^{11}\text{C}(p,\gamma)^{12}\text{N}$ and $^{12}\text{N}(p,\gamma)^{13}\text{O}$ reactions — relevant to the hot pp burning mode — and the $^{12}\text{C}(p,\gamma)^{13}\text{N}$ and $^{13}\text{N}(p,\gamma)^{14}\text{O}$ reactions, related to the (hot) CNO cycle. In all cases, the residual nucleus of the investigated radiative capture process was provided as radioactive beam by the RIKEN fragment separator [3] and was focused onto a Pb target foil. The reaction products were detected by a position sensitive hodoscope consisting of horizontal and vertical plastic scintillator bars to allow energy loss and energy signals, which were used for particle identification. In order to improve the relative energy resolution and to reduce the background, the hodoscope was in a vacuum chamber. Time of flight determination of the breakup fragments was also possible, since the target-hodoscope distance was more than 5 m.

The results will be compared to that of experiments using low-energy radioactive beams in inverse kinematics, and previous studies using similar approach with the exception of the $^{12}\text{N}(p,\gamma)^{13}\text{O}$ reaction, where neither direct nor indirect study has been made yet.

Zs. Fülöp acknowledges the STA fellowship managed by JISTEC, Japan.

- [1] G. Baur and C. Bertulani, *Nucl. Phys.* **A458**, 188 (1986).
- [2] T. Motobayashi et al., *Phys. Lett.* **264B**, 259 (1991).
- [3] T. Kubo et al., *Nucl. Instr. Meth.* **B70**, 309 (1992).

Half-Life Determination of ^{44}Ti Using a Radioactive Beam Technique

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In order to perform a meaningful analysis of the observed results of the $E_\gamma = 1157$ keV line — characteristic to the decay of ^{44}Ti — in the Cassiopeia A supernova [1] and the recently discovered RX J0852.0-4622/GRO J0852-4642 supernova remnant [2], an accurate determination of the half-life of ^{44}Ti is necessary. In a recent measurement [3], where the absolute activity of a sample has been determined several times, a period of 20 years was needed to reach an error level of 2%.

The availability of ^{44}Ti as radioactive ion beam offers an alternative method to determine the half-lives via implanting a known amount of ^{44}Ti into a stopper, and to measure the activity relevant to the decay of ^{44}Ti . Our aim was to establish a method that allows an absolute half-life determination with minimum systematic error and maximum versatility. It is also desirable that the measurement should give a reasonable error without years of data-taking. In our approach, the secondary beam is optimized not for the highest available intensity, but to reach an isotopic ratio where the time-of-flight (TOF) technique is enough for the separation. Since thin plastic scintillators placed upstream the stopper can be used for TOF, the isotopic ratio can also be monitored under high-intensity irradiation. Details about the preliminary tests, secondary beam production, the irradiation and the off-line activity measurement setup have already been published elsewhere [4].

In summary, we have implanted 2.7×10^9 ^{44}Ti ions into the stopper, and during the off-line measurement the count-rate in the detector relevant to the 1157 keV (^{44}Ti -related) peak was 50 counts/hour. On the other hand, the measured photo-peak efficiency is 1.3×10^{-2} in the used source-detector geometry. Our preliminary half-life value for the ^{44}Ti is 62.1 ± 1.6 y. The relative error of this method is comparable to the previous measurements, although only one day of irradiation and two weeks of activity measurement were necessary. Preliminary studies showed that the presented method can be applied to isotopes ^{39}Ar and ^{32}Si .

Zs. Fülöp acknowledges the STA fellowship managed by JISTEC, Japan.

- [1] A.F. Iyudin et al., *Astron. Astrophys.* **284**, L1 (1994).
- [2] B. Aschenbach et al., *Astron. Astrophys.* **350**, 997 (1999).
- [3] F. E. Wietfeldt et al., *Phys. Rev.* **C59**, 528 (1999).
- [4] Zs. Fülöp et al., in *Proc. "Nuclei in the Cosmos V"*, edited by N. Prantzos and S. Harissopulos, (1998) p. 281.

In-Beam Spectroscopy of Neutron-Rich Nuclei at the $N = 28$ Closed Shell

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 R. Lucas,[†] S.M. Lukyanov,[†] V. Maslov,[†] J. Mrazek,[†] C. Moore,[†]
 Yu.-E. Penionzhkevich,[†] L. Petizon,[†] F. Sarazin,[†]
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Onset of deformation in the neutron-rich Si, S and Ar isotopes at or around the $N = 28$ closed shell has been suggested by many authors both experimentally and theoretically. Experimentally the $^{44,46}\text{Ar}$, ^{45}Cl , $^{38,40,42,44}\text{S}$ and ^{43}P nuclei were studied via β -decay and Coulomb excitation [1, 2, 3, 4]. The measured short half-lives were attributed to the onset of deformation in this region. This assumption is in a good agreement with the results of the shell model calculations by Retamosa et al. [5] which describe the properties of these neutron-rich nuclei and predict the erosion of the $N = 28$ closed shell due to the large neutron-excess in these isotopes.

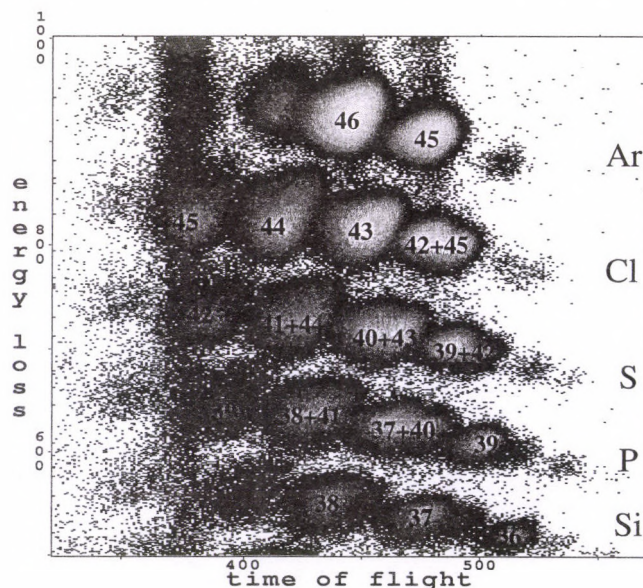


Fig. 1: The relevant part of time-of-flight – energy-loss matrix.

An experiment has been carried out at GANIL using fragmentation of the ^{48}Ca beam on a thin Be target. The γ rays coming from the excited fragments have been

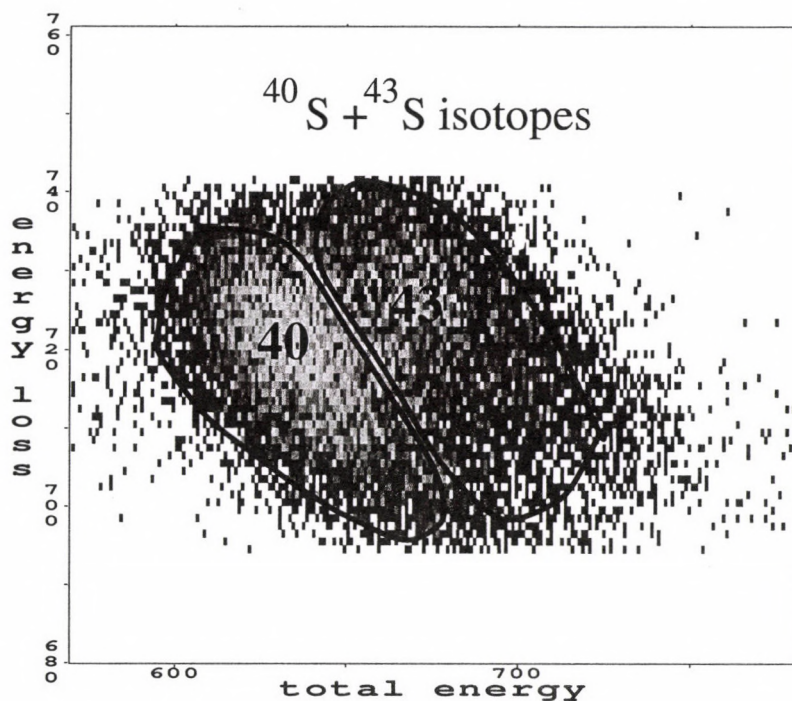


Fig. 2: The total-energy – energy-loss matrix for the ^{40}S and ^{43}S nuclei.

detected with BaF_2 and HPGe (coaxial and segmented clover) detectors mounted around the target. For identification of the fragments the SPEG spectrometer was used. Approximately 25 million heavy fragments have been detected. Events containing the energy and time parameters of the γ rays and the fragments have been stored on magnetic tapes.

During the off-line analysis the produced fragment nuclei have been separated by their time of flight, energy loss and total energy parameters. In Fig. 1 the relevant part of the time-of-flight – energy-loss matrix shows that the different Z and A nuclei are well-separated in this plot. However, some bunches correspond to two isotopes due to the appearance of recharged ions at A/Q ratios similar to those of the fully stripped ones. For example, the third bunch in the S-chain contains the fully stripped ^{43}S and the recharged ^{40}S isotopes. In order to separate the different charged states total-energy – energy-loss matrixes gated by the corresponding time-of-flight – energy-loss contours were produced. This separation can be seen in Fig. 2 for the ^{40}S and ^{43}S nuclei.

In the studied region the $^{45,46}\text{Ar}$, $^{42-45}\text{Cl}$, $^{39-44}\text{S}$, $^{37-41}\text{P}$ and $^{36-38}\text{Si}$ are identified. The analysis of γ -ray spectra of these nuclei are in progress.

- [1] H. Scheit et al., *Phys. Rev. Lett.* **77** (1996) 3697.
- [2] T. Glasmacher et al., *Phys. Lett.* **B395** (1997) 163.
- [3] O. Sorlin et al., *Phys. Rev. C* **47** (1993) 2941.
- [4] O. Sorlin et al., *Nucl. Phys.* **A583** (1995) 763.
- [5] J. Retamosa et al., *Phys. Rev. C* **55** (1997) 1266.

Proton Capture Cross Section of Sr Isotopes

Gy. Gyürky and E. Somorjai

The p-process nuclei are the proton-rich nuclides that are blocked from production in the r- and s-processes by stable nuclei. Calculation of the abundances of the p-process nuclides typically requires extensive numbers of reaction rates (many of which are either (p,γ) or (γ,p) reactions). Very few cross sections relevant to these processes, which involve light ions on relatively heavy nuclei, have been measured at energies appropriate to astrophysics [1], leaving these reaction networks dependent upon theoretical estimates calculated through statistical models.

In our work we measured the (p,γ) reaction cross section of three Sr isotopes using activation technique. The targets consisted of SrF_2 layers evaporated onto carbon backing. Natural Sr was used which allowed us to determine the capture cross section of ^{84}Sr , ^{86}Sr and ^{87}Sr in a single activation measurement. After proton irradiation (which lasted between 6 and 24 hours) the gamma activity of the targets was measured with a high purity Ge detector. In case of ^{84}Sr and ^{86}Sr the cross section of proton capture leading both to the isomer and ground state of the corresponding Tc isotope could be determined. The investigated energy range between 1500 and 3000 keV was covered with 100 keV steps.

The measurements were carried out with the 5 MV Van de Graaff accelerator of the ATOMKI. The data evaluations are in progress. As an example, the preliminary results concerning the $^{86}\text{Sr}(p,\gamma)^{87}\text{Y}^m$ reaction can be seen in Fig. 1.

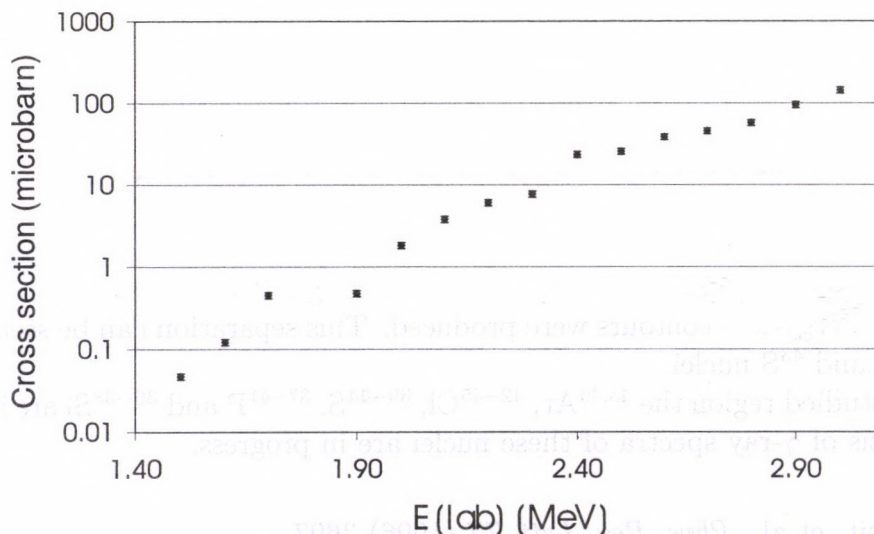


Fig. 1: Measured cross section of $^{86}\text{Sr}(p,\gamma)^{87}\text{Y}^m$ reaction (preliminary results)

[1] F.R. Chloupek et al., *Nucl. Phys.* **A652** (1999) 391 and references therein.

Low-lying Levels and High-Spin Band Structures in ^{102}Rh

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The level structure of the odd-odd nucleus ^{102}Rh produced in the heavy-ion induced reaction $^{70}\text{Zn}+^{36}\text{S}$ at 130 MeV has been investigated using the EUROGAM array. Many low-lying levels and four high-spin bands have been observed.

An interpretation of the low-lying levels and of the two two-quasiparticle bands is given by comparison with IBFFM calculations. Although the interacting boson fermion fermion model was developed for description of low-spin states, from the beginning it was used for the interpretation of one-proton-one-neutron high-spin states, too. The present calculations give a consistent description of both the low-spin states and the one-proton-one-neutron high-spin states in ^{102}Rh using a single set of parameters and a well defined Hamiltonian. The obtained results reveal the complex structure of this nucleus. The results have been published in Ref. [1].

The low-spin states are proton-neutron multiplet states involving $g_{9/2}$ and $p_{1/2}$ proton and $d_{5/2}$, $g_{7/2}$ and $h_{11/2}$ neutron orbitals. All of these states are mixtures of basis states with different numbers of d-bosons.

The lowest-energy negative- and positive-parity bands are assigned to be based on the $\pi g_{9/2}\nu h_{11/2}$ and $\pi p_{1/2}\nu h_{11/2}$ multiplets, respectively. According to the calculations the increase of spin along the bands is generated mainly by the increase of the number of d-bosons in their wavefunctions.

The observed two higher-energy, positive-parity bands are assigned as four-quasiparticle bands involving one $g_{9/2}$ proton, two $h_{11/2}$ and one $g_{7/2}$ (or $d_{5/2}$) neutrons using cranking calculations with modified oscillator potential.

[1] J. Gizon et al., *Nucl. Phys. A* **658** (1999) 97.

First Identification of γ Rays Assigned to ^{103}Sn

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An in-beam γ -spectroscopic experiment aimed at studying excited states of the very neutron deficient nucleus ^{103}Sn has been performed at the Legnaro National Laboratory. The $^{54}\text{Fe} + 240 \text{ MeV } ^{58}\text{Ni}$ reaction was used to populate nuclei in the vicinity of the double magic ^{100}Sn nucleus. For detection of the emitted γ rays the EUROBALL detector system, consisting of 15 cluster and 26 clover detectors, was applied. In order to select the corresponding reaction channels the evaporated charged particles were detected by a $\Delta E - E$ Si telescope ball. In addition, 50 liquid scintillators were mounted in the forward direction to detect neutrons. During the experiment about 10^9 events were collected.

In the above mentioned reaction the $2\alpha n$ channel leads to the ^{103}Sn nucleus. Comparing the $2\alpha n$ spectrum with the ones gated on higher multiplicity proton events the proton emitting channels could be discarded. The transitions from the strongest contaminating nucleus ^{65}Ge populated in the $^{16}\text{O} + ^{58}\text{Ni}$ reaction, were also identified. γ -ray spectra obtained by gating on $2\alpha n$ and $2\alpha np$ events are shown in Fig. 1. As it can be seen, we could assign the 168 keV γ ray to the ^{103}Sn isotope. Up to now only the ground state in this isotope was known.

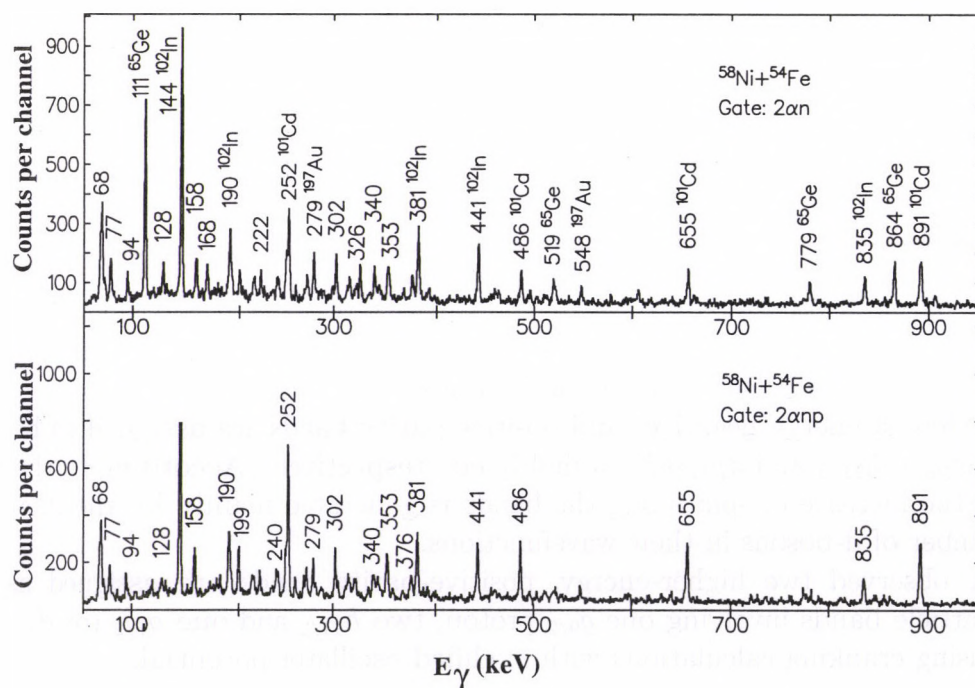


Fig. 1: Projections gated by $2\alpha n$ and $2\alpha np$ particles.

Configuration Assignment and Decay of ^{126}La High-Spin Bands

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It has been shown recently [1] that the $\pi h_{11/2}\nu h_{11/2}$ bands in the light Cs isotopes systematically exhibit signature inversion at relatively low spins. This phenomenon is expected when one of the valence nucleons lies in a low- Ω orbital of a high- J shell while the other nucleon is placed on a high- or medium- Ω orbital of a high- j shell. In the light La nuclei similarly to the Cs case the proton Fermi level lies just below the $[550]1/2^-$ low- Ω Nilsson orbital while the neutron Fermi level is close to the $[523]7/2^-$ orbital at the middle of the $h_{11/2}$ subshell. On the basis of this fact one can expect signature inversion for the $\pi h_{11/2}\nu h_{11/2}$ bands in the light La isotopes, too. These bands are known in the La isotopes, however there is no unambiguous spin-parity assignment for them until now, and therefore the signatures are not known either.

High spin states of ^{126}La have been populated using the reaction $^{116}\text{Sn}+^{14}\text{N}$ at 68 MeV. γ -rays and conversion electrons were detected with the GAREL array. Multipolarities of the lowest-lying in-band dipole transitions have been determined from the deduced internal conversion coefficients. Experimental $B(M1)/B(E2)$ ratios have been derived for the bands and compared with calculated values using the Dönauf-Frauentorf geometrical model. Configurations are proposed for the bands comparing them with cranked shell model calculations and on the basis of the measured $B(M1)/B(E2)$ ratios. The β -decay of ^{126}La has also been revisited. The population of the ^{126}Ba levels gives a tentative spin value of five for the decaying high-spin ^{126}La state with $T_{1/2} \approx 64$ s which may indicate a signature inversion in the $\pi h_{11/2}\nu h_{11/2}$ band [2].

[1] T. Komatsubara et al., *Nucl. Phys. A* **557** (1993) 419c.

[2] J. Timár et al., *EPJ A* **7** (2000) 7.

Mass Distribution of Fission Fragments from ^{236}U Hyperdeformed States

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In a recent work [1] experimental evidence for hyperdeformed states in U isotopes was given. From such highly elongated nuclear states much narrower fission fragment mass distribution is expected than from non-resonant fission, as predicted in a recent calculation [2].

An experiment on ^{236}U was carried out at the Debrecen 103-cm isochronous cyclotron, using 10 MeV deuteron beam. Enriched up to 97.6% and $88 \mu\text{g}/\text{cm}^2$ thick target of ^{235}U was used and $^{235}\text{U}(\text{d},\text{pf})^{236}\text{U}$ reaction was produced.

The essence of the experiment was the measurement of the time-of-flight (TOF) distribution of the two fission fragments in coincidence with the outgoing protons in order to get information on mass distribution of the fission fragments originated from the decay of the hyperdeformed states.

The energy of protons was analyzed by a split-pole magnetic spectrograph with a solid angle of 2.5 msr, which was set at $\Theta_{\text{lab}} = 125^\circ$ with respect to the deuteron beam direction. The position and energy of the analyzed protons were measured at the focal plane of the spectrograph by a position-sensitive silicon solid-state detector. The proton energy resolution of the spectrometer was better than 20 keV, measured for the peak of elastically scattered deuterons.

Fission fragments were detected by two multiwire position-sensitive avalanche detectors (PSAD) [3] placed in opposite directions at 55° and 125° regarding their centerlines. Both detectors had two wire-planes with delay-line read-out, each having a sensitive area of 16 cm x 16 cm. The geometrical arrangement of the detectors allowed us to achieve a solid angle of 4% for one PSAD. The two wire-planes with wires perpendicular to each other made the determination of the fission fragment entrance position in both x and y -direction possible, from which the TOF differences originating from different length of flight could be corrected. The TOF information from the two wire-planes in the same detector also allowed us to check the time resolution of the system, which proved to be 1 ns FWHM.

Proton energy spectrum is shown in the upper part of Fig. 1, where resonance structures corresponding to hyperdeformed bands in ^{236}U are seen at 5.28, 5.37 and 5.47 MeV excitation energies [1]. Some on-resonance and off-resonance regions of interest are indicated with different shadowing.

TOF spectra of fission fragments in coincidence with the on-resonance and off-resonance regions of interest have been accumulated, corrected for random coincidences and fitted with symmetric double Gaussian functions. Comparison of the

FWHM's of the Gaussian's fitted to TOF spectra, in coincidence with on-resonance and off-resonance protons, is shown in lower part of Fig. 1. It is clearly seen, that the widths of time-of-flight distributions in case of on-resonance protons (i.e. for hyperdeformed states) are significantly lower than in case of off-resonance protons.

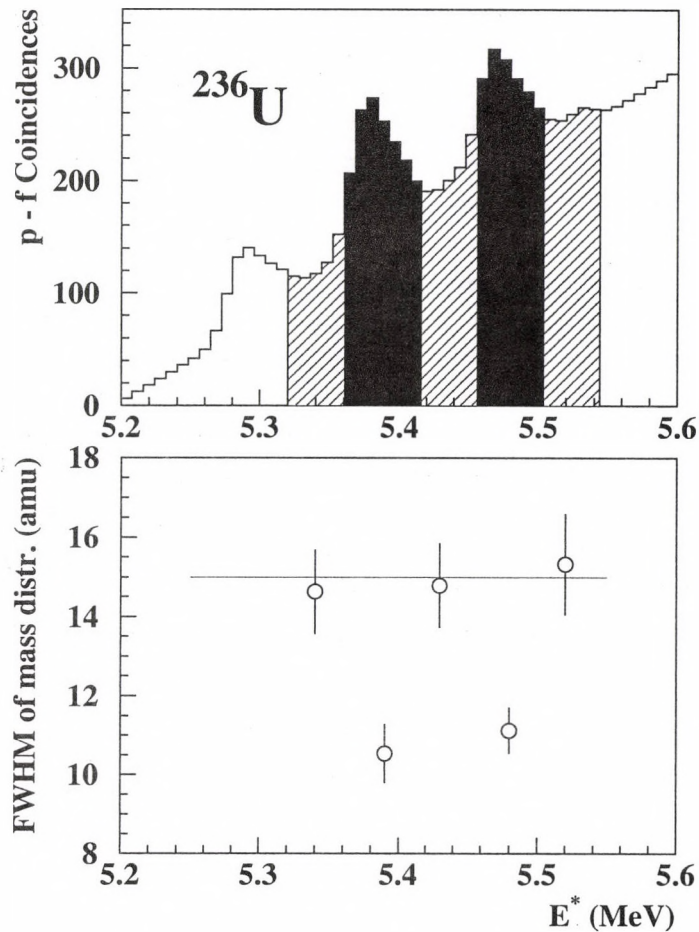


Fig. 1: Proton energy spectrum (upper part), where resonance structures correspond to hyperdeformed bands in ^{236}U . Comparison of the FWHM's of the Gaussian's fitted to the TOF spectra, in coincidence with on-resonance and off-resonance protons (lower part).

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Perturbative Quantum Chromodynamics

Z. Trócsányi

In recent years the idea of an infrared-regular effective strong coupling at low scales (the strong coupling ‘freezing’ or, more rigorously, the ‘dispersive approach’ of Dokshitzer, Marchesini and Webber [1]) has been employed for estimating hadronization corrections to various hadronic event shapes, using perturbative calculations. In our work [2], we computed power corrections to mean values of hadronic event shapes — the thrust T and the C parameter — of tagged b quark events in electron positron annihilation, using the dispersive approach. We found that the leading power corrections are of the same type of $1/Q$ corrections as for event shapes in the massless case, with the same non-perturbative coefficient times a perturbatively calculable mass-dependent coefficient. To show the effect of the mass correction, we plot our prediction $F^{(C)}$ for the mean value of the C parameter in Fig. a and $F^{(t)}$ for $t = 1 - T$ in Fig. b as a function of the centre-of-mass energy. The solid lines show the results for the central value of the $\overline{\text{MS}}$ b -quark mass at the given hard scattering scale run from $m_b(m_b) = 4.3$ GeV. The dotted line is the next-to-leading order perturbative prediction, with mass effects included, and the dashed lines represent the result when mass effects are present in the perturbative prediction plus power corrections without mass effects. We can observe that (i) the power corrections increase the perturbative prediction significantly and (ii) the mass effect in the power correction in tagged b samples reduces the latter by 10–30% for tagged b events, for centre-of-mass energies ranging from the Z^0 peak down to 20 GeV, and the effect is important for centre-of-mass energies below about 45 GeV.

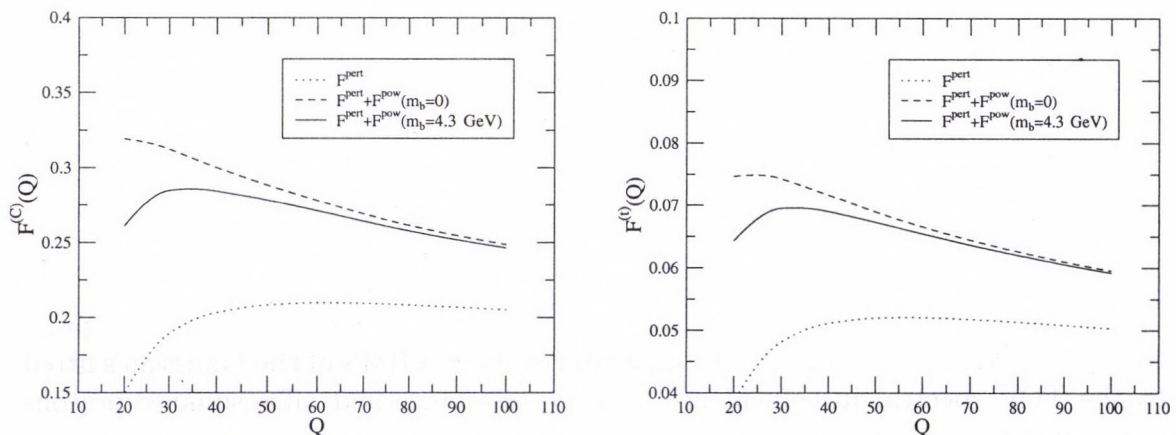


Fig. 1: Mean value of (a) the C parameter and (b) $1 - T$, where T is the thrust. Dotted: next-to-leading order perturbative result, dashed: perturbative + power correction without mass effect, solid: perturbative + power correction with mass effect.

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α -Clustering in Be Nuclei: An Algebraic Approach

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The consistent description of the berillium isotopes ($A = 7, \dots, 12$) represents a serious challenge to many nuclear models. This is because the structure of these nuclei changes significantly with increasing neutron number, furthermore, various states of the same Be nucleus may also show rather different features.

We performed a systematic study of the Be isotopes in terms of the semimicroscopic algebraic cluster model (SACM) [1] assuming ${}^4\text{He}+{}^{A-4}\text{He}$ cluster configurations. In the $\text{SU}(3)$ dynamical symmetry limit the basis states can be labelled by $[[f_1 f_2 f_3 f_4]ST(\lambda_C, \mu_C), n_\pi; (\lambda, \mu)K_L L J]$, where $[f_1 f_2 f_3 f_4]ST(\lambda_C, \mu_C)$ are the $\text{U}^{ST}(4)$ and $\text{SU}(3)$ quantum numbers of the ${}^{A-4}\text{Be}$ nucleus in the Elliott model, n_π stands for the number of oscillator quanta assigned to the relative motion, while $(\lambda, \mu)K_L L$ are the quantum numbers characterizing the orbital structure of the united system in the Elliott model. The SACM model space in the first few shells is then

$\hbar\omega$	${}^7\text{Be}$	${}^8\text{Be}$	${}^9\text{Be}$	${}^{10}\text{Be}$	${}^{11}\text{Be}$	${}^{12}\text{Be}$
0	(3,0)	(4,0)	(3,1)	(2,2)	(2,1)	(2,0)
1	(4,0)	—	(6,0),(4,1)	(5,1)	(4,2)	(4,1),(3,0)
2	(5,0)	(6,0)	(7,0),(5,1)	(8,0),(6,1),(4,2)	(7,1),(6,0),(5,2),(4,1)	(6,2),(5,1),(4,0)

The energy formula we used to generate the spectrum of the α -cluster states was

$$E = E_0 + n_\pi \hbar\omega_A - \chi C_2(\lambda, \mu) + \frac{1}{C_2(\lambda, \mu)} \left(a_K K_L^2 + a_L L(L+1) + a_J J(J+1) \right).$$

We fitted the parameters to the spectra for each nucleus (using $\hbar\omega_A = 45A^{-1/3} - 25A^{-2/3}$ MeV) and our main conclusions regarding the Be spectra are the following.

- i) The occasional inversion of the shell structure (as in ${}^{11}\text{Be}$) can be explained with the competition of the second and third terms of the energy formula: this is because the $C_2(\lambda, \mu)$ values are much larger in the $1\hbar\omega$ (and $2\hbar\omega$) shells than in the $0\hbar\omega$ one.
- ii) The long negative-parity band built on the $J^\pi(E_x) = \frac{3}{2}^- (3.96 \text{ MeV})$ state of ${}^{11}\text{Be}$ can be interpreted as a band from the $2\hbar\omega$ shell with $(\lambda, \mu) = (7, 1)$, which appears at this low energy for the same reasons.
- iii) The characteristic staggering pattern of some bands in the spectra of odd Be isotopes is well described by the last two terms of the energy formula, which reproduce exactly the same sequence as the Coriolis coupling term used in other models.
- iv) The $J^\pi(E_x) = \frac{1}{2}^- (0.32 \text{ MeV})$ state of ${}^{11}\text{Be}$ cannot be described in terms of ${}^7\text{He}+\alpha$ clusterization, rather it can be assigned to another $\text{U}^{ST}(4)$ configuration, which can be obtained by assuming ${}^8\text{Li}+{}^3\text{H}$ configuration, for example.

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On the Shell Model Connection of the Cluster Model

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The interrelation of basic nuclear structure models is a longstanding problem. The connection between the spherical shell model and the quadrupole collective model has been studied extensively, and symmetry considerations proved to be especially useful in this respect. A collective band was interpreted in the shell model language long ago [1] as a set of states (of the valence nucleons) with a specific SU(3) symmetry. Furthermore, the energies of these rotational states are obtained to a good approximation as eigenvalues of an SU(3) dynamically symmetric shell model Hamiltonian.

On the other hand the relation of the shell model and cluster model is less well explored. The connection of the harmonic oscillator (i.e. SU(3)) bases of the two approaches is known [2], but it was established only for the unrealistic harmonic oscillator interactions. Here we investigate the question: Can an SU(3) dynamically symmetric interaction provide a similar connection between the spherical shell model and the cluster model, like the one between the shell and collective models? In other words: whether or not the energy of the states of the cluster bands, defined by a specific SU(3) symmetries, can be obtained from a shell model Hamiltonian (with SU(3) dynamical symmetry).

We carried out calculations within the framework of the semimicroscopic algebraic cluster model [3, 4], in which not only the cluster model space is obtained from the full shell model space by an SU(3) symmetry-dictated truncation, but SU(3) dynamically symmetric interactions are also applied. Actually, Hamiltonians of this kind proved to be successful in describing the gross features of cluster states in a wide energy range. The novel feature of the present work is that we apply exclusively shell model interactions. The energies obtained from such a Hamiltonian for several bands of the (¹²C, ¹⁴C, ¹⁶O, ²⁰Ne, ⁴⁰Ca) + α systems turn out to be in good agreement with the experimental values.

The present results show that the simple and transparent SU(3) connection between the spherical shell model and the cluster model is valid not only for the harmonic oscillator interactions, but for much more general (SU(3) dynamically symmetric) Hamiltonians as well, which result in realistic energy spectra. Via the shell model, the cluster picture is connected to the quadrupole collective model, too.

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Spectroscopic Factors of Alpha-Like Clusters

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The appearance of exotic ($A > 4$) clusters in atomic nuclei is a topic of great current interest. E.g. the importance of ^{12}C clusterization in the ground state of light nuclei was conjectured recently [1] in relation with low-energy heavy-ion reactions. In particular, a new kind of anomalous transparency was found in ^{12}C scattering [2], which seems to show up due to an interference between the elastic scattering and elastic transfer processes. The target dependence of this effect is in line with the qualitative considerations on the possible ^{12}C clusterization of the target nucleus, based on the application of a simple $\text{SU}(3)$ selection rule to binary cluster configurations [1]. More quantitative investigation of these structural aspects is largely desirable.

Work is in progress in order to attack this problem based on the method invented by Horiuchi [3] and developed further by Katō [4] for the calculation of spectroscopic factors of multicluster systems. As the first step we systematically construct the Pauli-allowed model spaces of the $^{16}\text{O}+N\alpha$ and $^{12}\text{C}+N\alpha$ systems. Technically this amounts to determining the $\text{SU}(3)$ irreps and their multiplicities appearing in each oscillator shell of the unified nucleus in terms of the $\text{core}+(N-1)\alpha$ model spaces. Once having these bases, we can make calculations not only for the $\text{core}+N\alpha$ systems, but also for any cluster configurations that can be obtained from these by regrouping the $N+1$ clusters. For $^{12}\text{C}+3\alpha$, for example, we can also consider the $^{12}\text{C}+^{12}\text{C}$, $^{12}\text{C}+^{12}\text{C}^*$, $^{16}\text{O}+^8\text{Be}$ and other channels by rearranging the Jacobi coordinates associated with the relative motion degrees of freedom and by “freezing them in” in certain states. Up to now, we have extended the Pauli-allowed model space of the $^{12}\text{C}+3\alpha$ system to the $2\hbar\omega$ and the $3\hbar\omega$ shells; previously these were known only on the first two oscillator shells.

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Separation Energies from a Symmetry-Based Mass Formula for Non-Strange Nuclei and Λ Hypernuclei

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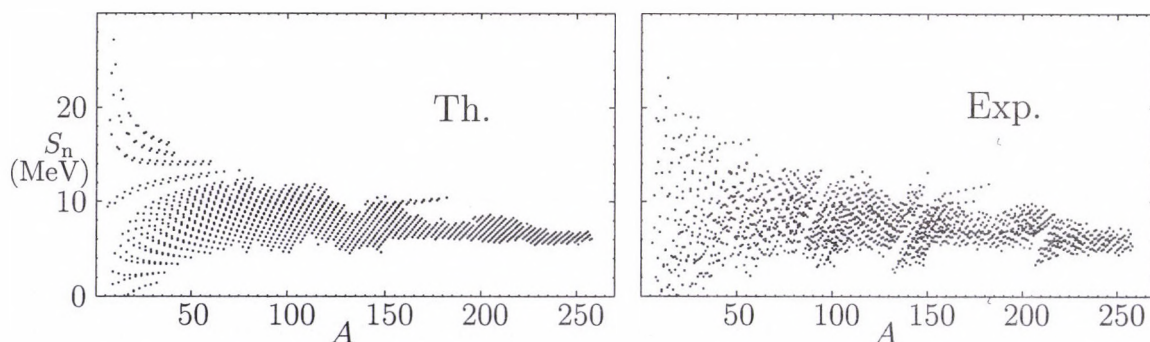
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Recently we have proposed a nuclear binding energy formula for the unified description of normal nuclei and Λ hypernuclei [1]:

$$B(N, Z, \Lambda) = a_v A - a_s A^{2/3} - a_c \frac{Z^2}{A^{1/3}} - a_a \frac{(N - Z)^2}{A} + a_y \frac{\mathcal{S}}{A^{\gamma_y}} + a_m \frac{\langle \hat{M} \rangle}{A^{\gamma_m}}.$$

Fitting the binding energies of these two types of nuclei separately and jointly in various mass regions, we found that the (sixth) Majorana term successfully replaces the pairing term of Weizsäcker's mass formula, furthermore, this term, together with the (fifth) strangeness term describes the binding energies of Λ hypernuclei, too.

As a further step, we analyzed nuclear and Λ separation energies for these nuclei [2]. Below we show the results for neutron separation energies $S_n = B(N, Z, 0) - B(N - 1, Z, 0)$ for normal nuclei. The theoretical plot was made using the parameter set obtained from a fit to nuclei with $N, Z \geq 2$.



The gaps in the experimental plot are due to shell effects, which are not accounted for by our formula. Work is in progress to incorporate these effects in our method.

We also compared our formula with that of Dover and Gal, which is the only other similar mass formula known to us.

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Atomic Physics

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Theoretical Study of Inner-Shell Ionization by Heavy-Particle Impact

L. Sarkadi

In our previous theoretical studies of inner-shell ionization of atoms by heavy-particle impact we applied the so-called *coupled-states model* [1]. This theory was constructed to account for the intra-shell coupling effects in L-shell ionization. The model satisfactorily reproduced the main tendencies of the measured L-shell ionization data (cross sections, L_3 -subshell alignment parameters) in a broad range of the collision energy, target and projectile atomic number. However, the accuracy of these calculations was uncertain, because the coupled-states model contained a series of approximation. The most questionable assumption was that the changes of the cross sections due to the subshell coupling effects were expressed by correction factors. The correction factors were derived considering only some representative transitions between the bound and continuum states, namely transitions into states of energy $E_f = 0$ and angular momentum $l_f = 0, 1$.

As a first step to improve the coupled-states model, a computer program was developed [2] to calculate the matrix elements of the Coulomb interaction between a charged particle and an atomic electron, $\int \psi_f^*(\mathbf{r}) |\mathbf{R} - \mathbf{r}|^{-1} \psi_i(\mathbf{r}) d\mathbf{r}$, for arbitrary final state energy E_f and angular momentum l_f . The $\psi_k(\mathbf{r})$'s are non-relativistic hydrogenic wave functions. The program consists of subroutines that compute matrix elements between eigenstates of both the total angular momentum j , and the orbital angular momentum l . As further output quantities, the radial components of the multipole series expansion of the matrix elements (the so-called G functions) can be obtained, as well. The structure of the program is such that the hydrogenic wave functions can be replaced by arbitrary one-electron wave functions.

The program was tested in calculations of K-, L- and M-shell ionization probabilities and cross sections within the framework of the straight-line version of the (first-order) semiclassical approximation (SCA) approach. The obtained results agree with the tabulated values of Hansteen [3] within the accuracy given by the authors (less than 5%), except for the M_4 and M_5 subshells, where larger deviations (up to 50%) were observed. According to one of the authors [4], the reason might be a convergence problem in the old calculations.

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Electron Capture to the Continuum Induced by Dipolar Interaction

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The process of *electron capture to the continuum* (ECC) leading to cusp (a singularity in the energy spectrum of the forward ejected electrons in atomic collisions) is well understood for the case when the interaction between the outgoing projectile and the electron is the long-range Coulomb force. In the present study [1] we considered the ECC cusp electron production by dipolar force which is characterized by short range. Dipolar interaction may arise in such collision systems where the outgoing projectile is an excited H0 atom. For example, for the $n = 2$ excitation the collisional mixing of the degenerated 2s and 2p states in H⁰ may lead to a permanent electric dipole moment. An indication for the existence of the dipolar cusp was found in studies of the single-electron detachment from H⁻ [2].

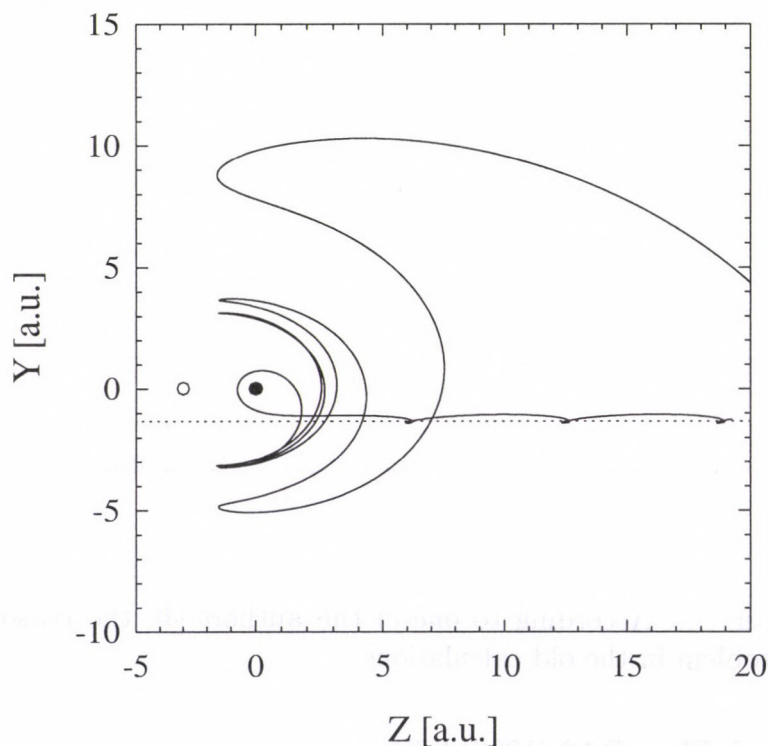


Fig. 1: Electron trajectory leading to cusp for collision of a 25 keV dipole particle with a H atom. The trajectory is plotted in the projectile-centred reference system. Notations: —, electron; - - - , target nucleus; the full and open circles represent the positive and negative particles of the dipole, respectively.

To analyze the problem, we applied a three-body *classical trajectory Monte Carlo* (CTMC) model. We demonstrated that under suitably chosen collision conditions

the intensity of the dipolar cusp can exceed that of the proton-induced cusp. This finding is an important step towards the understanding of the experimental data obtained for the ECC cusp by neutral hydrogen atom impact [3]. In spite of the fact that the replacement of the H^0 projectile (in excited state) by a dipole particle is a very crude approximation, the present investigations revealed some general features of the dipolar cusp that go beyond the applied model. Here we refer, first of all, to the *new mechanism of cusp production* found in the present work: The formation of two-center quasi-stationary orbits (states) that lead to emission of very low-energy electrons in the projectile frame (see Fig. 1). One may assume that such states can be formed not only for a dipole but also for an excited outgoing H^0 projectile, provided the latter develops an electric dipole moment throughout the collision.

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Hot Electrons in Intermediate Velocity (150–250 keV/u) Ion–Atom Collisions: Multiple Scattering of the Ejected Electrons

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We have found experimental signatures (peaks, structures in the electron spectra) of consecutive projectile–target–projectile–target–etc. scattering of the emitted electrons before ejection at atomic targets. This type of multiple scattering is often referred as Fermi shuttle mechanism [1, 2, 3, 4, 5, 6], the electrons are sometimes called Ping-Pong electrons.

The experiment has been performed at the beamline of the 5 MV electrostatic accelerator in ATOMKI in 150 and 233 keV/u collisions of singly charged He, C and O ions and inert gas (He, Ne, Xe) targets. The ejected electrons have been measured by the ESA-21 electrostatic electron spectrometer in the 10–3000 eV energy region, in 13 angular channels simultaneously (including at 0 and 180 degrees).

For C and O ions, the data provide evidence of double scattering at backward angles (at $2 V_p$). Moreover, for C+Xe and O+Xe collisions, we found a clear signature of triple scattering at forward angles ($4 V_p$) in the spectra of the emitted electrons. A small but significant structure at backward angles which might be associated with quadruple scattering has also been found at $4 V_p$. In the studied collision systems, the significant disagreement between theory and experiment at high electron energies seem to be dominantly due to the structures belonging to multiple scattering processes. Consequently, for high energy ejected electrons, one might associate the main process beyond first order in the intermediate impact velocity region with consecutive (P–T–P–...) multiple scattering.

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One- and Two-K-Shell Vacancy Production in Atomic Lithium by 95 MeV/u Bare Ar Projectiles

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Single K-shell excitation and double-K-shell-vacancy production in atomic Li by 95 MeV/u Ar¹⁸⁺ projectiles have been investigated. High-resolution Auger electron emission, occurring in the energy range 50–100 eV and resulting from the deexcitation of singly- or doubly-excited states, was measured for various electron emission angles. Both single-K-shell excitation and double-K-shell vacancy production show strong dependences on the electron emission angle, enabling the study of anisotropy effects for the specific Li configurations produced in the excitation process. Experimental anisotropy parameters for the ²P and the ²D states resulting from single-K-shell excitation are in reasonable agreement with predictions of the Born approximation. In the case of double-K-shell-vacancy (i.e. hollow ion or atom) production, the two K vacancies are found to come about mainly by ionization plus excitation of the atomic Li target giving rise to excited states in Li⁺.

Strong line intensities from the 2s² ¹S and 2s3s ³S excited-state configurations are explained in terms of shake processes, providing direct spectral identification for the electron–electron (e–e) interaction in producing the doubly vacant K-shell configurations. Production of the latter ³S state, which has an intensity greater than that of the ¹S state, is attributed to a three-electron transition involving two shake transitions. Production of the 2s2p ³P state is attributed to be largely (~60%) due to the dielectronic manifestation of the e–e interreaction resulting from slow electron emission.

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Electron Spectra from Collisions of 95 MeV/u Ar¹⁸⁺ Ions with He and Ne Atoms

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Double differential electron spectra emitted from He and Ne target atoms by fast heavy-ion impact were measured, extending the systematic study of the ionization of inert-gas targets [1, 2] to higher impact energies range. Helium and neon atoms were bombarded by 95 MeV/u Ar¹⁸⁺ ions and the double differential cross sections for electron emission have been determined. The measured angular distribution patterns exhibit significant differences between the two target species. Good agreement has been found between experiment and CDW-EIS theory for the helium target [3], while for neon experiment provides an angular distribution that differs from the theoretical prediction both in shape and magnitude at low electron energies. Since we found that theoretical neon data are rather sensitive to the wave functions, one might associate this finding with an inappropriate description of the atomic structure.

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Double Scattering of the Ejected Electrons in Ion–Atom Collisions

Cs. Koncz and B. Sulik

Double-scattering phenomena observed in ion–atom collisions have been reported recently by several groups [1, 2, 3, 4]. In these experiments ionization cross sections differential in the energy and emission angle of the ejected electron were measured. The observed new features of the spectra were explained by the classical picture of an electron which undergoes in two consecutive collisions with the heavy collision partners. For target ionization, e.g. in the first collision the electron gains a large momentum and energy from the projectile. In the second collision, the electron is elastically scattered by the target core.

A few calculations regarding this ionization mechanism were carried out within the framework of classical trajectory Monte-Carlo method [3, 4, 5] achieving a reasonable qualitative agreement with the experimental findings. In a recent work [6], a simple quantum mechanical model is constructed. A second-order Born approximation based on this model which uses plane waves in the final and intermediate states provides a qualitative description of the double scattering process. We draw attention to the fact that the usual first-order Born calculation with realistic target eigenfunctions in both the initial and final states also takes account of the double scattering process.

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A Coincidence Study between Photo- and Auger Electrons

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The investigation of double differential cross sections of photon induced Auger electrons provides very sensitive method for studying the rearrangement process, especially when the angular correlation between photo- and Auger electrons is also studied. Such type of measurements could reveal a new aspect in studying the electron-electron, hole-electron and photoelectron - Auger electron interactions. It enables one to separate the overlapping Auger lines belonging to different initial holes.

The traditional coincidence measurement is very time consuming and causes serious calibration problems. In order to overcome these experimental difficulties a

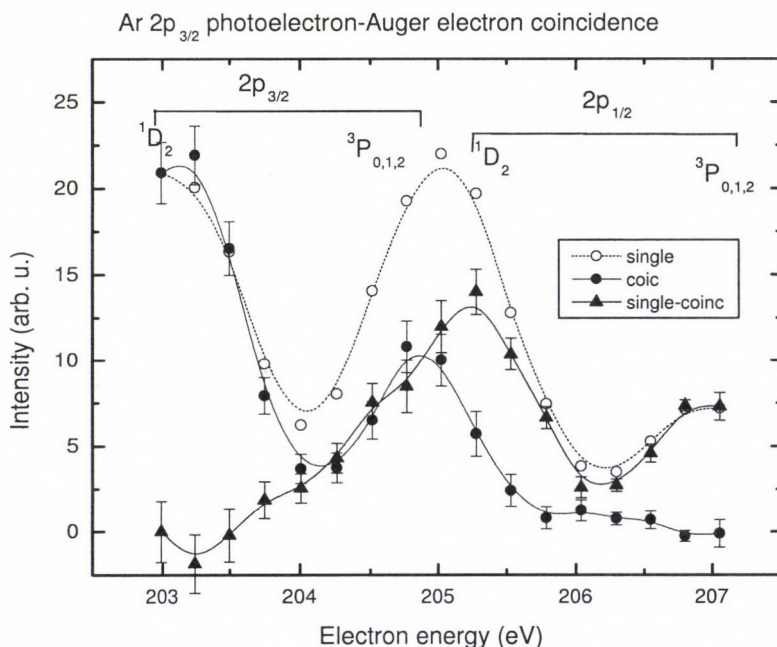


Fig. 1: shows a part of the L_{23} - $M_{23}M_{23}$ Auger spectrum of argon at 350 eV photon impact. The open black circles represent the well-known single Auger spectrum (without coincidence condition), the violet close circles show the coincidence spectrum and the blue triangles are the differences between the normalized single and coincidence spectra (the lines are drawn only for guiding the eyes).

new electron-spectrometer (ESA-22) was developed in ATOMKI, Debrecen in cooperation with the Electron spectroscopy group of University of Oulu, Finland. The analyzer consists of a spherical and a cylindrical part. It is very similar to the ESA-21 analyzer [1]. The main difference is that the focal ring can be set different diameters thus either a series of channel detectors can be used to detect the electrons at different angles or a position sensitive channel plate can be applied for simultaneous angular recording of electrons. Furthermore, the outer sphere and cylinder are cut into two parts so the spectrometer is capable to analyze two independent angularly resolved electron spectra (in the $0^\circ - 180^\circ$ region) at different energy regions, simultaneously. A special electronic control and data handling electronics and software was worked out to control the analyzer. The first results were presented in [2,3].

In the last year the ESA-22 electron-spectrometer was transported to the I411 beam line of MAX-II synchrotron in Lund, Sweden. The advanced properties of the spectrometer was investigated by measuring coincidences between the photoelectrons originated from the Ar L_3 subshell and the Ar Auger electrons in the 203–207 eV energy region. Fig. 1 shows the single and the coincidence spectra. It is clearly seen that the overlapping Auger lines belonging to the L_2 and L_3 initial states can be separated with the coincidence condition.

This high efficiency coincidence measurement opens a new way to investigate the ionization and rearrangement process.

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L-Shell Ionization in Collisions of Heavy Ions with Low Z Atoms

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The $K\alpha$ X-ray spectra of Ca, Ti, Cr and Fe induced by C, O and Ne ions were measured by means of a high-resolution von Hamos Bragg crystal spectrometer [1]. The energies of the ions provided by the variable energy cyclotron of the Paul Scherrer Institute in Villigen, Switzerland were 2–18 MeV/amu which covered a wide domain of the projectile reduced velocity (1.5 to 4). The intensity distributions of the KL^N satellite lines, which are result of the multiple inner shell ionization, were used to obtain the probabilities for direct ionization of the single L shell electron in a near-central collision with heavy ions.

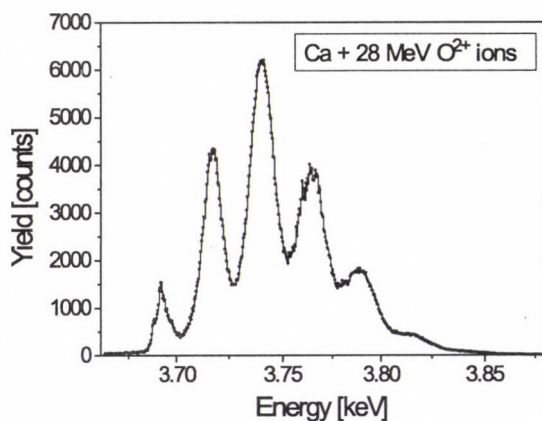


Fig. 1: The measured KL^N satellite spectra of Ca target after bombardment with 28 MeV O^{2+} ions.

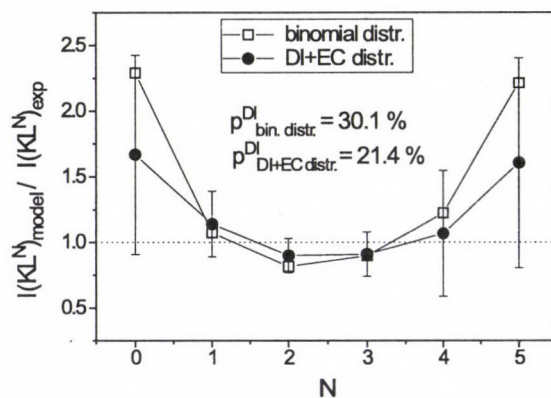


Fig. 2: The ratio of the experimental KL^N vacancy yields and the yields obtained from fitting two different distributions describing the multiple KL^N ionization.

Significant discrepancies from the binomial distribution were observed. With the incorporation of the electron capture into our KL^N distribution model, the discrepancies were reduced, although not completely solved. In order to avoid systematic error which can be incorporated in the final ionization probabilities, it is necessary to take into account the electron capture besides the direct ionization. This is important especially at lower projectile's energies where capture is more significant. The capture probabilities obtained within the CTMC calculation were incorporated into the distribution model in order to obtain reliable direct ionization probabilities. The

results are compared to the theoretical predictions within the SCA approximation [2] and with the CTMC calculation.

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Examination of the Charge State Distribution of Ions in the ECR Ion Source

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The Electron Cyclotron Resonance (ECR) Ion Source of ATOMKI offers the possibility for up-to-date experiments in the field of atomic and plasma physics and for practical applications. Also the methods of the production of highly charged ions are objects of active research. As in the ion source the particles are confined in small volume magnetic traps, the examination without disturbing the plasma is mainly focused on the radiation emitted by them.

In the course of our experiments we examine the spectral distribution of x-rays emitted by the plasma of the ECR Ion Source. For the measurements we use a solid state x-ray detector of PIN diode type. With the knowledge of the response function and the efficiency of the detector the recorded spectra can be analyzed and important plasma parameters can be determined from them. During the measurements the detector was situated outside the vacuum chamber so in the course of the analysis also the x-ray transmission of different materials (a 100 μm kapton foil; 25 cm air; 25 μm Be window) had to be taken into account.

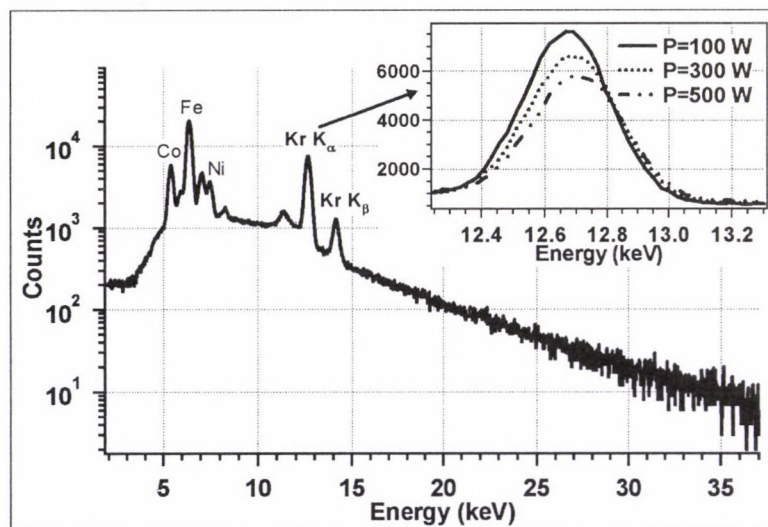


Fig. 1: A typical x-ray spectrum

We recorded x-ray spectra by different settings of the ECRIS and we studied the effects of the tuning parameters on the spectra. In our measurements Ar and Kr gases were used and we analyzed the position of the K_{α} peak of the working gas incorporating the above detector functions. The shift of the above mentioned peak gives us information on the change of the average ion charge of the plasma.

Figure 1 shows a typical x-ray spectrum. We can observe three components in the spectrum: the bremsstrahlung of the electrons, the characteristic lines of the working gas and the characteristic lines of the excited wall materials.

X-ray spectrum of Kr ECR plasma and the Change of the energy position of the Kr $K\alpha$ peak as a function of the power of the microwave field.

We plan to continue these measurement using a higher resolution x-ray detector and we will plan to compare the measured charge state distributions with model calculations, which determine this distribution on the basis of theoretical atomic and plasma physics.

An Improved Description of the Multiple Ionization KL^i Satellite Energy Spacings

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In analytical works, and in basic atomic physics research one needs the data of the satellite lines, therefore we began to make a new compilation of the energy shifts of the $K\alpha L^i M^m N^n \dots$, $K\beta L^i M^m N^n \dots$ satellites, and $K^2\alpha L^i M^m N^n \dots$, $K^2\beta L^i M^m N^n \dots$ hypersatellites. A byproduct of this compilation is a test of the "classic" description of their energy spacings as a function of Z [1]. The larger database we have now, made it possible, to obtain a better description. For $K\alpha L^i$ satellites, see Ref. [2]. The old version gave equidistant spacing also for the $K\beta L^i$ satellites, using an average effective Z seen by the electrons: $\Delta E(K\beta L) = 4.38Z_L = 4.38(Z - 4.15)$, our version uses an effective Z changing with the number of spectator L vacancies:

$$\Delta E(K\beta L^i) = i \times 3.37[Z + (i - 1) \times 0.5 - 5.37], \quad i = 1, 2, 3, \dots, 7.$$

This equation, obtained by fitting a representative portion of our compiled data is in agreement with experimental data, perhaps the $i = 7$ case is a little bit underestimating them, probably because of the significant number of additional M , N vacancies. Full account is given in a paper in preparation.

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* ORNL is managed by Lockheed Martin Energy Research Corporation under contract No. DE-AC05-96OR22464 with the U.S. Department of Energy.

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High Resolution Carbon and Oxygen K-LL Auger Spectra of Carbon Dioxide

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The proton excited carbon and oxygen K-LL Auger spectra of carbon dioxide were measured using the high-resolution, angular resolving ESA-21 electron spectrometer. The 1.0 MeV proton impact energy was provided by the 5 MV van der Graaff accelerator of ATOMKI. The transition energies of both K-LL Auger-spectra (oxygen and carbon) are determined and compared with the existing theoretical and earlier experimental data. The energy positions, line widths (FWHM) and relative intensities of the Auger lines were determined by the experiment.

Satellite transitions are apparent in both Auger spectra. Some peaks in the spectra have contributions from configuration interactions, double Auger, shake-up and shake-off Auger satellites. Most probably, the assumed linear background does not include all satellite contributions of the spectra. By using synchrotron radiation, it is possible to ionize atoms and molecules selectively in order to produce a *clean* Auger spectrum. By comparing such a spectrum with an Auger spectrum produced by particle impact it is possible to identify satellite Auger structures. For the further study of the carbon and oxygen K-LL Auger spectra of CO₂, synchrotron radiation excited measurements with photon energies just above the ionization potential of carbon and oxygen 1s shell are needed.

This work is continuation of the angular distribution investigation of the Auger electron spectra made in ATOMKI. One of the previous measurements was made with a diatomic homonuclear molecule (N₂) [1], where noticeable angular distribution was found for few transitions only. For triatomic, heteronuclear molecule (CO₂), the possible anisotropy of the angular distribution of the Auger emission was also studied, and the Auger lines in both spectra (C and O) were found to be isotropic within the experimental accuracy [2].

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Glory and Rainbow Effects in Ion-Atom Collision

Gy. Víkor

Post-collision interaction (PCI) is a Coulomb interaction between charged particles originating from an ion-atom collision. It is always present when more than two charged particles leave the collision area. We studied PCI effect calculating the energy shift and the intensity of the Auger line, for the Auger electrons emitted from the Ne target during its relaxation. For large impact energies (MeV/u energy region), the projectile has small influence on the target relaxation. Even then, PCI can cause line distortion and intensity enhancement that essentially changes the shape, energy and intensity of the Auger line (Kuchiev and Sheinerman [1]). The effect shows resonant-like behavior, and it is the most intensive in the beam direction. Up to now, only the influence of the attractive Coulomb field has been studied, for structureless, positively charged projectiles (mostly protons).

Calculating the Ne K-L_{2,3}L_{2,3} (¹D₂) Auger line using quantum-mechanical theory of Barrachina and Macek [2] (see also Kuchiev and Sheinerman [3]), the antiproton induced PCI was investigated (repulsive Coulomb field). the antiproton induced PCI is compared with the recently obtained results for the high-energy proton induced PCI [4]. In opposite to the known Coulomb focusing PCI, for antiproton impact the repulsive Coulomb field causes a large line-intensity decrease that appears for projectile velocities smaller than the Auger electron velocity (*Coulomb defocusing PCI*). Also, the energy shift and the distortion of the Auger line for the antiproton shows a behavior that is opposite to the proton induced PCI [5].

According to the theoretical work of Samengo and Barrachina (and references therein) [6], it is clear that the focusing and defocusing effects can equally occur with any other central potential, provided the scattered particles emerge from a point source. Therefore, the focusing and defocusing PCI can be more general named as *glory effect and rainbow effect*, known from optics. This was already suggested by Samengo and Barrachina [6].

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Materials Science and Analysis

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Chemical Effects on F KLL Auger Spectra in Fluorides

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The satellite structures of the F KLL Auger spectra of fluorides have been studied extensively recently [1, 2, 3] in order to obtain information on the origin and the atomic or molecular character of the particular Auger satellite lines. The understanding of the nature of these Auger transitions is important for surface chemical identification, for determining the electronic structure of these fluorides and for clarifying the role of the various excitation and relaxation processes which can contribute to the corresponding spectral lines.

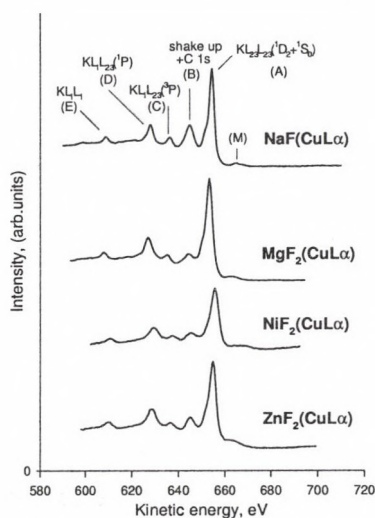


Fig. 1: F KLL Auger spectra of rutilite-type difluorides excited by Cu L α X-rays.

F KLL Auger spectra (Fig. 1) were excited by Al K α and Cu L α X-rays from MgF₂, ZnF₂, NiF₂ and CoF₂ polycrystalline powder samples and measured by a high luminosity electron spectrometer [4]. The application of Cu L α X-rays proved to be useful to increase the peak to background ratio in the spectra considerably. The measured F KLL spectra are compared to F K α X-ray spectra obtained earlier using photon and energetic ion impact [3], as well as to resonant Auger spectra induced by synchrotron radiation [2]. Similarly to the case of the alkali-metal fluorides [3], unassigned peaks (denoted by (M) in Fig. 1) were found in the F KLL Auger spectra of the rutilite-type difluorides. The observed Auger and X-ray satellite structures can be interpreted satisfactorily on the basis of a new concept, the resonant orbital rearrangement (ROR) model [3], in terms of atomic excitation and cluster molecular orbital calculations.

This work was supported by the projects OTKA T026514, MTA-JSPS 24/1998.

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Influence of the Grain Size on the Magnetic Properties of Ball-Milled $\text{Fe}_{90}\text{W}_{10}$

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There are many indications in the literature that the saturation magnetization (M_s) decreases only a few percent with the grain size, and the observations on larger decrease are interpreted mostly by oxygen absorption, characteristic to the preparation technique. In the nanometer range, where the grain size is comparable to or is even smaller than the effective domain-wall width, the magnetic properties undergo fundamental changes. Below the so called magnetic exchange length (L_{ex}), the grain size dependence of coercivity (H_c) is controlled by the random anisotropy model (RAM), which predicts a steep decrease of H_c below L_{ex} . To study the grain size dependence of saturation magnetization M_s and coercivity H_c , Fe(W) nanocrystalline solid solutions with 10 at% W content have been produced by ball milling of elemental Fe and W powders.

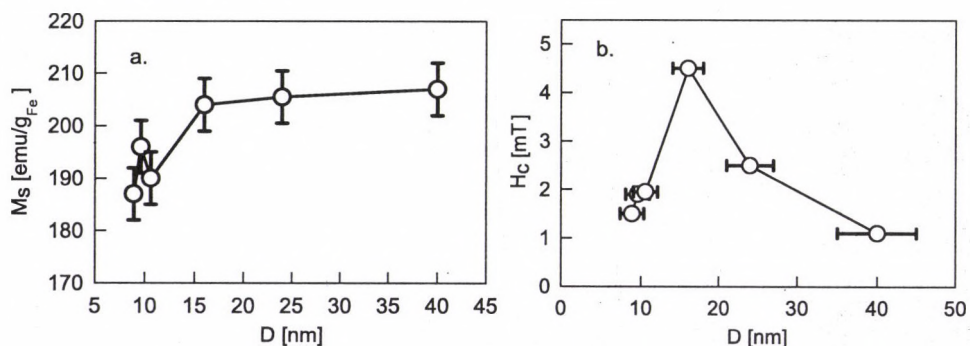


Fig. 1: Grain size dependence of saturation magnetization (a) and coercivity (b)

The ball milling of the powder mixture was performed at ambient temperature in a hardened stainless steel vibrating mill under vacuum. The structural study by X-ray diffraction showed the formation of b.c.c. solid solution of W in Fe and the decrease of grain size to cca. 9 nm. The magnetization measurements at room temperature were carried out by a vibrating sample magnetometer up to 1 T field.

The results are demonstrated in Fig. 1. The saturation magnetization (M_s) decreases from the initial 207 emu/g_{Fe} by cca. 10% during the milling process. Most of this change however can be ascribed to the formation of Fe(W) solid solution. The coercivity (H_c) has a maximum at grain size of about 16 nm and a steep decrease at smaller grain sizes. The latter is probably due to the decreased anisotropy constant, which leads to a sharp decrease in coercivity according to the random anisotropy model.

Metastability line in phase diagram of vortices in BSCCO

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Nonlinear transport in the low temperature vortex glass state of single crystal $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$ has been investigated with fast current pulses driven along the ab plane. Field cooled (FC) preparation shows a higher threshold current (marking a jump or break in slope in the voltage response) than the zero field cooled (ZFC) one. The higher threshold FC state is *metastable*: by perturbing the field by a few hundred Oe up or down and returning to the starting value, the $V-I$ characteristic is converted to be very close to that of the ZFC prepared state. Once the perturbation is effected, the conversion takes place continuously over a few minutes. The locus of the peak in the ZFC threshold value separates a low temperature region, where metastable states exist, from a high temperature region where a unique, preparation independent and apparently stable $V-I$ characteristic is found.

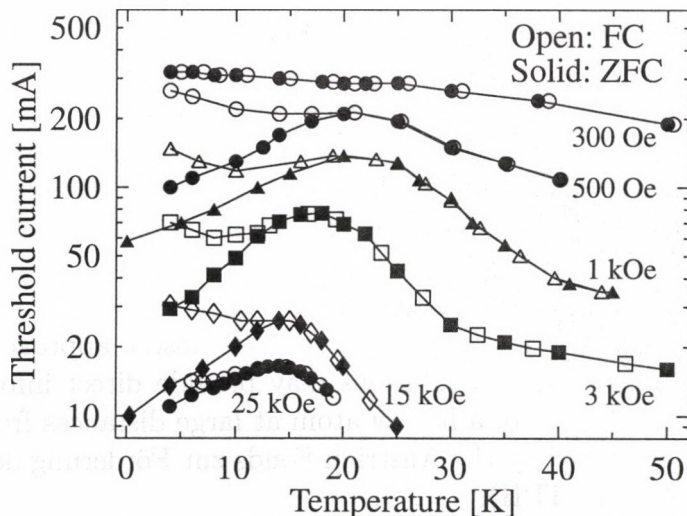


Fig. 1: Temperature dependence of threshold current at fixed fields for FC and ZFC prepared samples, measured on increasing the temperature above the initial preparation temperature.

Transmission of Highly Charged Ions through Microcapillaries

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Studies of the interactions of highly charged ions (HCI) with surfaces are of growing interest. From a number of experimental as well as theoretical studies [1, 2] the following picture of the HCI-surface interaction has emerged: When a highly charged ion approaches a solid surface, one or more electrons are resonantly captured at a characteristic distance into Rydberg states of the projectile [1]. As a result, a multiply excited Rydberg atom with inner shell vacancies, a so-called hollow atom, is created. Recently, a novel technique has been introduced to study hollow atoms by interaction of highly charged ions with internal surfaces of microcapillaries [2]. In this work, transmission of HCI through microcapillaries is studied theoretically by a classical trajectory Monte Carlo method. The interaction of an HCI with the internal surface of the capillary is treated within the framework of dielectric response. The impact parameter (b) and angular distribution of the highly charged ions formed in grazing collisions with the capillary surface are analyzed. As a projectile we consider Ne^{6+} with an energy of 2.1 keV/amu.

Similar to grazing incidence surface collisions the image acceleration of the HCI toward the wall manifests itself as a pronounced shift in the angular distribution towards larger scattering angles. We observed a banana-shaped θ - b correlation pattern with a very well localized angular distribution [3]. It is noteworthy that the angular distribution for each charge state is much narrower than the initial angular divergence of the beam. This is a direct consequence of the intrinsic high selectivity among all initial conditions which lead to transmission to the microcapillary accompanied by charge exchange of a given charge state. Low charge states are strongly correlated with closer fly-by's (small b 's) and larger scattering angles ($\theta = 1.25^\circ$) while the effective single capture channel ($q = 5$) extends from the threshold angle $\theta_c = 1.13^\circ$ for single capture to larger angles. The charge-state dependent correlation between scattering angle and distance of closest approach predicts that angular-resolved charge state distributions may provide direct information on the evolution of the charge cloud of a hollow atom at large distances from the surface.

The work was supported by the Austrian Fonds zur Förderung der wissenschaftlichen Forschung (P12470-TPH).

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Charge State Evolution of Highly Charged Ions Transmitted through Microcapillaries

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When a highly charged ion approaches a solid surface, one or more electrons are resonantly captured at a characteristic distance into Rydberg states of the projectile [1]. As a result, a multiply excited Rydberg atom with inner shell vacancies, a so-called hollow atom, is created. Recently, a novel technique has been introduced to produce long-lived hollow atoms by interaction of highly charged ions with internal surfaces of microcapillaries [2].

In this work, the charge state evolution of highly charged ions transmitted through microcapillaries is studied theoretically by a classical trajectory Monte Carlo method. We perform the simulations for a metallic microcapillary of Ni. As projectile we use N^{6+} with an energy of 2.1 keV/amu. We analyze the charge state distribution of outgoing N^{q+} ions for which experimental data are available [2].

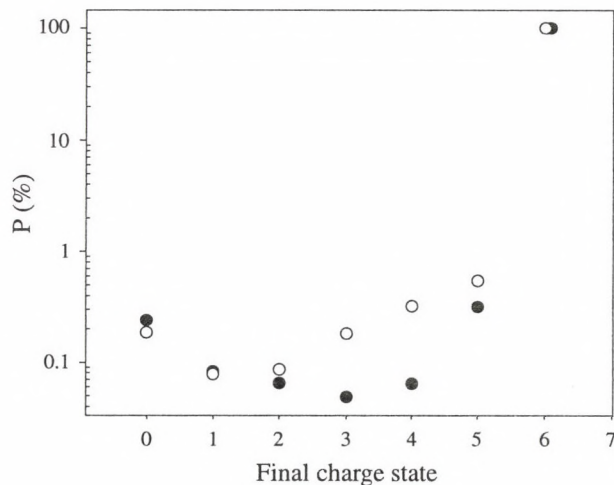


Fig. 1: Final charge state distribution of incident 2.1 keV/amu N^{6+} ions transmitted through a Ni microcapillary. Open circles: experiment [2], solid circles: simulation.

It is important to realize that the charge state distribution reaches its asymptotic stable limit only after the ion is about 100 m i.e. almost macroscopic distances, downstream from the exit surface when the Auger relaxation is complete. The present simulation gives overall good agreement for all ionic charge states on an absolute scale. The fairly flat and uniform distribution over all other charge states ($q = 0, 1, \dots, 5$) is a unique feature of distant collisions with the internal microcapillary surface, not previously observable in ion-atom, ion-solid and grazing ion-surface

collisions. There are, however, a few noticeable discrepancies for charge states $q = 3$ and 4 which correspond to electron configurations with a net capture of two or three electrons, respectively. Their apparent enhanced stability could possibly be due to the presence of extremely long-lived metastable configurations which are currently not yet included in the simulation.

The work was supported by the Austrian Fonds zur Förderung der wissenschaftlichen Forschung (P12470-TPH).

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Probe of Surface Dielectric Response Function by Microcapillary Transmission

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During the last decades, measurements of the energy loss suffered by fast electrons have been used for determining optical constants. The probability of the energy loss is determined by the imaginary part of inverse dielectric response function, $\epsilon^{-1}(k, \omega)$ which is a function of the frequency ω and the wavenumber k of the electromagnetic disturbance. Raether [1] pointed out that dielectric properties determined by electron energy loss spectroscopy (EELS) agree well with those obtained by optical methods. However, above about 30 eV, multiple-scattering events become significant and the measured bulk properties are surface sensitive, thereby complicating the extraction of $\epsilon(k, \omega)$. Heavy particles feature the advantage that for projectiles moving parallel to a planar surface the stopping power resulting from the dielectric response of the surface without direct (“hard”) collisions can be probed. However, since the ion is always attracted towards the surface by its self-image potential, it will suffer a close collision upon impact on the surface. This problem can be avoided using a microcapillary target. Ions traveling approximately parallel to the capillary axis also experience an image force towards the cylindrically shaped wall of the capillary but only a small fraction of ions will collide with the wall or capture electrons from the surface while most ions can escape from the capillary without hitting the wall and without charge exchange. Using transmission of highly charged ions through microcapillaries one can maintain all advantageous properties of EELS but can avoid disadvantageous features: Effects due to the multiple-scattering events are absent and there are no hard collisions with the target. This technique also permits to investigate distance dependent properties and promises to provide information about the surface dielectric response only because the ions pass by at large distance from the surface.

In this work we present a theoretical study of the energy loss of ions which undergo only grazing interaction with the capillary walls and do not experience charge exchange, but come close enough to the walls to suffer a significant stopping power. We perform the simulations for a metallic microcapillary of Ni. As projectile we use Ne^{10+} with an energy of 2.1 keV/amu. The dominant fraction of the incident beam will undergo only small angle scattering and suffer negligible energy loss (<1 eV). The amount of energy loss is strongly correlated to the distance of closest approach which also determines the strength of the interaction between the projectile and the solid surface. Larger energy loss (> 10 eV) should be experimentally observable for $\theta > 1^\circ$. Since scattering angle and distance of closest approach are strongly correlated, the distant-dependent stopping power and thereby the surface dielectric properties of the capillary material at large distances can be probed in detail.

The work was supported by the Austrian Fonds zur Förderung der wissenschaftlichen Forschung (P12470-TPH).

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Convoy Electron Spectra at Relativistic Energies

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In this work the transmission of relativistic Ar^{17+} with an energy of 390 MeV/u through carbon foils with thickness varying between 25 and 9190 $\mu\text{g}/\text{cm}^2$ is studied. The calculation is based on the solution of the Langevin equation. The random walk of the relativistic electron initially bound to the argon nucleus is followed by a Monte Carlo method. During the transport through the solid the electron suffers a series of stochastic elastic and inelastic collisions. As a result the projectile is excited or ionised. The shape and the full width at half maximum (FWHM) of our simulated electron spectra at 0° (convoy electron spectra) are in good agreement with the recent experimental results [1, 2]. The FWHM is initially decreasing for increasing thickness due to a higher probability for ELC from intermittently formed Rydberg states and subsequently increasing because of the longer random walk of electrons in the solid subsequent to ionisation leading to enhanced collisional broadening of the spectrum.

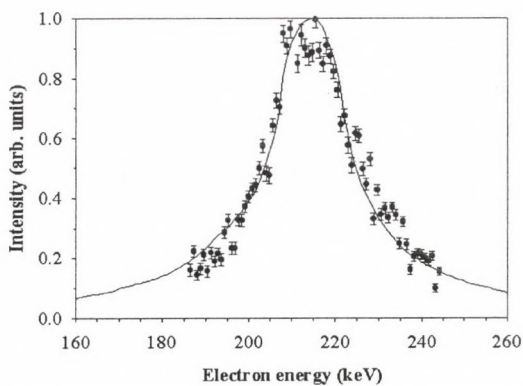


Fig. 1: Convoy electron spectrum at 0 observation angle for a carbon foil with thickness of 50 $\mu\text{g}/\text{cm}^2$. Circles: experiment [1], solid line: present Monte Carlo simulation.

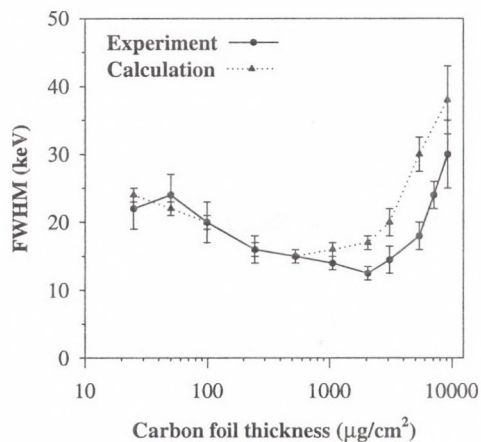


Fig. 2: FWHM of the the convoy electron spectra in forward direction as a function of foil thickness. Circles: experiment [1], triangles: present Monte Carlo simulation.

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Inelastic Mean Free Path for Relativistic Collisions

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Recent experimental results with high-energy projectiles enable a probe of inelastic collision theory for finite momentum transfer q .

The inelastic scattering processes of the electron in the solid are well described in terms of dielectric response theory, in which the dielectric function $\epsilon(q, \omega)$ as a function of momentum and energy transfer describes the response of the medium. The dielectric response can be decomposed into longitudinal and transverse components. The doubly differential cross section is expressed by the energy loss function $\text{Im}(-1/\epsilon(q, \omega))$. The dielectric function $\epsilon(q, \omega)$ is determined in terms of a sum of Drude-type functions, which emphasize the influence of single particle interactions for large momentum transfer and interactions with plasmons for small momentum transfer. The resulting $\epsilon(q, \omega)$ satisfies the generalized Thomas–Reiche–Kuhn sum rules.

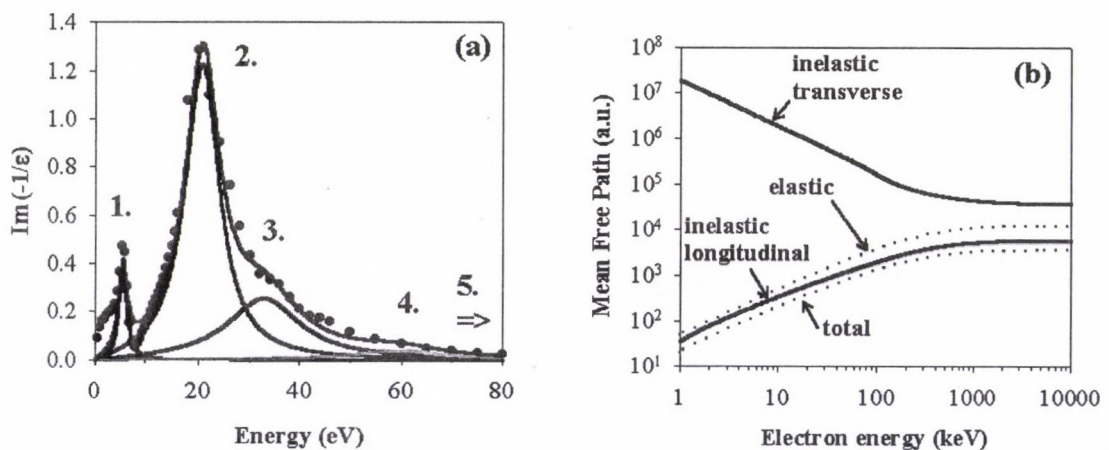


Fig. 1: (a) Energy loss function of carbon. Circles: derived from experimental optical data; solid line: fit to the experimental results using a sum of Drude-type functions. (b) The MFP's as a function of the electron energy.

Figure 1a) shows the energy loss function determined from experimental optical data and the fit to the experimental results. With the help of $\epsilon(q, \omega)$ the inelastic mean free path (MFP) can be calculated (Fig. 1b). The contribution of the longitudinal component to the total mean free path decreases with increasing energy, while the transverse component becomes more significant in the relativistic energy region.

Ion Beam Studies in the Field of Arts, Archaeology and Geology

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Obsidian [1]

The natural volcanic glass material means a great interest both in archaeometry and in geology. It was important trade item for prehistoric people as raw material of many kind of artefact. From the geological point of view different type of obsidian melts are sensitive geochemical indicators for Earth processes. The accurate determination of elemental constituents of obsidians in both research fields is important.

Based on the light element concentration data measured by Proton Induced Gamma-Ray-Emission (PIGE) method a distinction among samples resulted via various magmatic processes with diverse provenances is achieved. This was made possible by exploiting the excellent characteristics of our Clover-Ge-BGO detector system [2]. Using this instrument the determination of the concentration of lithium, an important trace element, became available. A comparison with the analysis of heavier elements carried out by Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) technique is done.

Dyrrhachium Silver Coins [3]

Analytical characterization of ancient silver coins (drachmas) issued by the Greek city Dyrrhachium 68-43 years BC was carried out by micro-PIXE method. Out of a 153 pieces Dyrrhachium drachma collection of the Coin Cabinet of the Hungarian National Museum 27 ones were analysed including four ancient imitations. The aim of this investigation was to involve the Hungarian artefacts into a comprehensive and systematic study of the coin-hoards discovered in the neighbourhood of Hungary (e.g. in Romania) in the framework of an international collaboration (COST G1).

For the Hungarian and Romanian coins the same extent of degradation of the fineness of silver was observed (Ag = 92%) comparing to the ones minted in the second century BC. Sn proved to be a characteristic element for imitations (Sn = 1%). Another new result is that iron x-ray peaks are localized into <20 μm regions, i.e. iron is present in the samples either in the form of surface contamination or inclusions.

[1] Z. Elekes et al., Nucl. Inst. Meth. **B161-163** (2000) 839.

[2] Z. Elekes et al., Nucl. Inst. Meth. **B158** (1999) 209.

[3] I. Uzonyi et al., Nucl. Inst. Meth. **B161-163** (2000) 751.

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- [1] N. Elekcs et al., Nucl. Inst. Meth. B161-163 (2000) 839.
- [2] N. Elekcs et al., Nucl. Inst. Meth. B158 (1999) 209.
- [3] I. Ukonvi et al., Nucl. Inst. Meth. B161-163 (2000) 751.

Earth and Cosmic Sciences, Environmental Research

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Isotope Geochemistry of Methane Dissolved in Formation Waters of S-E Hungary

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Methane present in subsurface waters originates from bacterial and thermal degradation of sedimentary organic matter. While bacterial methanogenesis takes place in the upper some hundred metres, the thermal generation of the methane starts only after the temperature reached 50–60 °C [1]. In most sedimentary basins such a temperature corresponds a depth of 1.5–2 km thus aquifers lying in the zone of the thermal methanogenesis are seldom tapped by water wells.

In hot basins, like the Pannonian Basin, characterised by high heat flow the onset of the thermal methanogenesis is much shallower. On the other hand, the deep aquifers of the lacustrine Pannonian Basin mostly contain a water of low salinity and rather low chlorinity [2]. Due to these circumstances, a considerable number of wells are producing water from the deep aquifers of the S-E Hungarian part of the basin, expected to be already below the onset of the thermal methanogenesis. Hence this area is an ideal target for studying the geochemistry of methane in the subsurface waters.

Six water samples produced from below 1300 m depth have been studied for $\delta^{13}\text{C}$ of methane and CO_2 and for δD of methane. The isotopically very light methane, not accompanied by C^{2+} gases in detectable amount is clearly of bacterial origin. It is very probable that a part of the aquifers of the Hódmezővásárhely through, after the bacterial methanogenesis achieved but before the thermal hydrocarbon gas generation started in them, were vigorously flushed by practically methane-free waters of meteoric origin. These aquifers contain only thermogenic methane, generated probably in and migrated from either the neighbouring confining beds, more rich in organic matter or deeper lying sediments.

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Uncontrolled Tritium Release from Paks NPP

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Continuous monitoring of the observation wells around Paks NPP has been carried out since the starting of the NPP. Mostly tritium but sometimes fission and corrosion products were detected in the observation wells. To forecast their movement we constructed a groundwater flow model for the area. Visual MODFLOW was applied for this purpose. The groundwater flow in the Paks aquifer was modelled using values of Danube levels and rainfall heights from the period 1986–98. The aquifer has an upper sandy layer of cc. 12 m thick, below this there is a sandy gravel layer of 6.5 m average thickness. The water flow is the most intensive in the gravel layer of 21.5 m average thickness. The first impermeable clay layer below the gravel is not continuous and the area is characterised by upwelling of water through this layer. The eastern boundary of the area is the river, the limits on West and South can be defined by means of prescribed head boundaries. We calibrated the model by simulating the transient flow over a year calculating for 45 stress periods using measured river stage elevations and comparing the calculated water heads with the measured water levels of 102 observation wells. After achieving a good agreement between the measured and the calculated piezometric heads, this model served the input data for the MT3D transport code. This code was applied to calculate the tritium movement in the Paks aquifer by inverse modelling. Since 1992 the tritium concentration had been measured regularly in 40–45 observation wells, so it was possible to construct tritium distribution maps. Assuming possible sources and amount of tritium as input parameters we calculated the tritium distribution and compared the calculated data and distribution with the measured values and maps. We changed the input parameters till we achieved an acceptable agreement between the measured and calculated maps and values. This way we gave an estimation for the possible locations of the leakage, the total uncontrolled tritium release, the movement of the tritium in the future and its effect to the population. We found that the uncontrolled total tritium emission to the hydrosphere during the last ten years did not exceed 0.2 TBq. The average uncontrolled tritium emission is about 0.018 TBq/y. This amount is of the same magnitude as Danube carries in an hour.

The Effect of the Continuous Water Subtraction on the Quality of Drinking Water

Zs. Szántó, L. Palcsu and M. Molnár

In Debrecen the deep groundwater has been pumping for municipal water supply for 80 years and the amount of the extracted water has grown exponentially since 1950s. The groundwater extraction from the major aquifer is fairly large: the waterworks production reaches 20–25 million cubic meters annually. The continuous water subtraction from the aquifer modifies the flow patterns, water masses from the shallow groundwater layers move down and reach the lower aquifer. As a result of the mixing of the younger water coming from the upper aquifer and the old water in the deepest aquifer the radiocarbon ages along the cross section of the aquifer are decreasing in the direction of the main flow. It means that even the deepest aquifer is not protected against pollution from the surface [1, 2].

Repeated investigation was carried out on several wells of the Debrecen Waterworks in 1999. The results are summarised in Table 1.

Table 1: Tritium content and ^{14}C activities of water samples from wells of Debrecen Waterworks

Well	T [TU] (1999)	^{14}C pMC [‰] (1988)	^{14}C pMC [‰] (1999)
II Waterworks, 30	< 0.04	24.13 ± 0.30	21.80 ± 0.26
II Waterworks, 22	< 0.03	28.15 ± 0.28	26.60 ± 0.18
II Waterworks, 24	< 0.03	42.50 ± 0.41	41.80 ± 0.32
II Waterworks, 7	< 0.03	13.71 ± 0.31	28.30 ± 0.26
H.sámson, Waterworks I	< 0.03	18.72 ± 0.36	17.50 ± 0.31
Biogal 9	14 ± 0.2	50.87 ± 0.38	55.90 ± 0.30

One can see from Table 1 that the ^{14}C activity in the well No. 7 of II Waterworks has been doubled during ten years as a result of younger water inflow. The situation is even worse in the case of the well Biogal 9 where the tritium content as well as the ^{14}C activity of the water is typical of shallow groundwaters.

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Complex Water Analysis of the Observation Wells Situated around the Püspökszilágy Radioactive Waste Repository

Zs. Szántó, É. Svingor, I. Futó, M. Mihály and L. Palcsu

The long-term safety of an underground radioactive waste repository strongly depends on the radionuclide transport through the bedrock to the biosphere. The chemical composition of the groundwater has a large influence on the mobility of the radionuclides of interest and the movements of these nuclides are controlled by the groundwater flow.

In the frame of a large safety analysis programme of the Püspökszilágy radioactive waste treatment and disposal facility the observation wells situated around the radioactive waste repository were monitored.

26 water samples were taken during July and September 1999 and a complex water analysis was made. Püspökszilágy and Némédi streams flowing through the region of interest were sampled, as well.

Classical water analysis methods were used for determination anion concentration (especially PO_4^{3-} , SO_4^{2-} , HCO_3^- , Cl^- , CO_3^{2-} , NO_3^- , NO_2^-), ICP (*inductive coupled plasma*) technique was used for determination low level metal concentration (Hg, As, Pb, Cd, Co, Cr, Cu, Al, Fe, Ga, Li, Mo, Mn, Ni, Se, Sr, Ti, V, Zn) and AAS (*atomic absorption spectrometry*) method was applied for determination higher concentration of Ca, Na, K, Mg. Stable isotope ratios (δD , $\delta^{18}\text{O}$, $\delta^{15}\text{N}$, $\delta^{34}\text{S}$, $\delta^{13}\text{C}$) were measured by a home-developed mass spectrometer. ^{14}C activity concentration was measured by GPC technique. ^{90}Sr activity concentration was determined by liquid scintillation counting method (TRICARB 3170 TR/SL ultra low level liquid scintillation spectrometer), while ^{137}Cs and ^{60}Co activities were determined by a HPGe detector. Low level tritium concentrations were measured using the ^3He - ^3H method (VG 5400 noble gas mass spectrometer).

Water-mixing mechanism were determined, local water flow tendencies and a Püspökszilágy stream orientated water movement pathway were found, indicating a possible migration route for the water-soluble radioactive waste from the repository.

Isotope Geochemistry of Groundwaters and Dissolved Gases in the Aleurolit Formation near Mecsek Mountains, Hungary

E. Hertelendi, I. Futó, L. Palcsu and M. Molnár

Aleurolit formation near Mecsek Mountains (SW Hungary) is planned for use as a nuclear waste depository. Detailed environmental isotope studies were carried out in order to prove the suitability of the host rock. $\delta^{34}\text{S}$ values of sulfur bearing minerals and total sulfur of the aleurolit suggest that the aleurolit was formed in lacustrine environment. Lower and Middle Triassic gypsum occur above the aleurolit layers in various horizons therefore sulfur isotope ratios of dissolved sulfate were used to identify flow paths of groundwaters that had passed through different evaporitic sequences.

Mining activity during the last 40 years has modified the flow patterns of groundwater in the area which resulted younger groundwater ages. T-He³ analysis of the groundwater showed that the tritium concentration of 100 mTU is typical for the water appearances at the depth of 900 m in the aleurolit. Radiocarbon concentration of the water is less than 6 pMC.

Headspace gases of groundwater samples were analyzed. The most important components were nitrogen with delta value close to zero and hydrogen with delta value of less than -700 ‰. The methane in the headspace is bacterial origin. The dissolved Ar, Kr, Xe isotope variations arose from mixing of atmospheric derived components in groundwater and crustally produced radiogenic Ar from ⁴⁰K decay as well as Kr, Xe from spontaneous fission of ²³⁵U in the rock matrix. The abundance of ⁴He in dissolved helium is much higher than in the atmospheric helium, which clearly shows that significant part of helium is derived from α -decay of U and Th.

^{226}Ra in Geothermal Waters of the Carpathian Basin

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Due to favourable geology of the Carpathian Basin many natural springs and drilled wells produce geothermal waters enriched in minerals. They represent significant economic and therapeutic value on which world famous bathing places developed in past centuries. Chemical composition of these waters has been extensively studied but less attention was paid to their radioactivity. Radon and radium content of waters may be interesting from different points of view. First, too much radon and radium in drinking water may pose health risk for humans. Second, radon and radium can be useful in tracing underground water transport. Therefore, cheap, reliable and accurate measurement of their concentrations has a great value. Etched track detector based simple method was developed in the Institute of Nuclear Research, Debrecen in the last years [1, 2].

In this work the radium and radon contents of thermal water of the springs and wells of the Gellért, Rác and Lukács Baths as well as of the Rudas Drinking Hall in Budapest were measured. Samples from drinking-water wells of Feked, Szébeny, Véménd (near the Mecsek Mountain in Transdanubian region of Hungary) and about 50 mineral water samples were collected in Hargitha County, Transylvania of Romania; in Slovenia and in the Great Hungarian Plain. The majority of the Romanian and Slovenian mineral waters have from low to moderate ^{226}Ra activity concentration ($<300 \text{ Bqm}^{-3}$). The Hungarian geothermal waters show higher values up to some kBqm^{-3} .

^{222}Rn and ^{226}Ra determination of other well-known medical waters are planned. Further studies of commercially available bottled mineral waters and of dosimetric consequences due to daily consume of these measured waters are in progress.

This work was supported by the National Scientific Research Fund, No. T-22985.

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Temporal Changes in the Gas Composition of a Cave Atmosphere

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Continuous measurements of ^{222}Rn , CH_4 , NMHC, NO_x , CO, CO_2 , SO_2 and O_3 gases together with temperature and pressure of the atmosphere of the Cserszegtomaj well-cave, Keszthely Mountains, SW Hungary, were taken to characterize the climate of the cave and to study subsurface-atmospheric transport processes.

The observed concentrations for the studied components were in the range ^{222}Rn : 0.5–17 kBq/m³; CO_2 : 0.9–2.95 %v/v, O_3 : 0–110 mg/m³; CH_4 : 2000–4000 mg/m³; NMHC: 2000–6000 mg/m³; SO_2 : 3–10 mg/m³.

We have observed periodic dilution or enhancement of ^{222}Rn , NO_x , CH_4 , O_3 gas components with 12 h or 24 h periods. The effect was interpreted by periodic intrusion of the above surface atmosphere into the cave atmosphere controlled by diurnal pressure changes. In contrary, longtime pressure changes were dominantly controlling ^{222}Rn and CO_2 levels in the cave.

This work was supported in part by the National Scientific Research Fund, contract Nos. T016558 and T017560.

Study of Single Aerosol Particles Collected in Urban and Cave Environment by Proton Microprobe

Zs. Kertész, I. Borbély-Kiss, I. Rajta, I. Uzonyi and Á.Z. Kiss

As part of our atmospheric aerosol research a number of cascade impactor samples were collected in a speleotherapeutic cave situated under Budapest (Szemplőhegy-cave), and at an urban location in Debrecen during February, 1998. The urban samples were collected in the yard of the Institute, where aerosol samples have been collected for years. Sampling in the cave were done in the sites of the speleotherapy. Samplings were carried out using a 7-stage PIXE International cascade impactor, which allowed the separation of the aerosol within the size range of 0.25 μm and 30 μm into 7 fractions: particles with aerodynamic diameter of 0.25–0.5 μm , 0.5–1 μm , 1–2 μm , 2–4 μm , 4–8 μm , 8–16 μm and 16 μm or larger.

Major and trace element concentrations (above Al) of about 600 aerosol particles were determined with the use of the scanning proton microprobe of the ATOMKI. Hierarchical cluster analysis was carried out to identify the particle groups. The contribution of the different types of particles to each size fraction, the possible chemical composition of the particles and their sources were investigated.

The most abundant groups of particles in both cases are silicon and calcium rich particles, although the Ca to Si ratio in the cave is higher, and there are more Ca-rich particles (about 60%) in the cave than in the urban environment (35%). Iron, titanium, sulphur and potassium particles were also found.

In the case of *cave aerosols*, the coarse size fractions (particles with aerodynamic diameter larger than 2.5 μm) contains particles of clearly crustal origin (presumably the mixture of CaCO_3 and alumino-silicate compounds). The fine size fractions contains alumino-silicate particles with 20% Ca and Fe content containing S, Cu and Zn compounds. In most cases the K:Al:Si ratio is constant. This indicates that these particles most probably originate from the clay layer of the cave, to which sulphur, zinc, copper and chlorine compounds of anthropogenic origin are attached. The 2–4 μm size fraction consists of particles in which Ca is the dominant element, although this type of particles can be found in the coarse and also in the fine size fractions. Besides Ca high amount of S, P, Cl and V can be found most probably in the form of CaCl , CaSO_4 , CaPO_4 . The main source of S and V is oil and coal combustion. Chlorine may come from the salting of the roads.

In the case of the *urban aerosol particles* in the coarse size fractions and in the 2 μm or smaller size fractions alumino-silicate and iron-oxide particles were the most abundant ones which most probably originates from soil characteristic to the wider Debrecen region. Ca-rich particles were found mainly in the 2–4 and the 4–8 μm size fractions. These particles contain rather high amount of K, S, Cl, P and Zn compounds of anthropogenic origin. The main source of these elements is oil and coal combustion.

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Preliminary Study of Elemental Mass Size Distribution of Urban Aerosol Collected in Debrecen

Zs. Kertész, I. Borbély-Kiss, Á.Z. Kiss, E. Koltay and Gy. Szabó

Aerosol sampling campaigns were performed during January–February 1998 and August 1998 at an urban location (in the yard of the Institute of Nuclear Research), where aerosol sampling has been carried out continuously since 1991 with single stage Nuclepore filter holders, and since 1994 with 2-stage Gent stacked filter units (SFU).

In the winter period in four weekdays 24-hours samplings were performed with a 7-stage PIXE International Cascade Impactor (PCI) and simultaneously with a SFU. On 19–25 August 1998, a week-long aerosol sampling campaign was carried out with the PCI (24-hour samplings), a SFU (24-hour samplings), and a streaker sampler (168-hour continuous sampling). For this period meteorological data were also obtained by a micro-meteorological station installed at the same location by the Radon Group.

Elemental concentrations for Al, Si, P, S, Cl, K, Ca, Ti, V, Mn, Fe, Ni, Cu, Zn, Ba and Pb of the aerosol samples were determined by PIXE using the 2 MeV energy proton beam of the 5 MeV Van de Graaff accelerator of the Institute.

The obtained average elemental concentrations and the seasonal variation in the elemental concentrations show good correlation with the results obtained from the analysis of the samples collected in previous years. In winter the elemental concentrations are usually lower than in summer, except Cl. The Cl concentration in the coarse fraction is higher with a factor of 10 than in summer due to the salting of the roads and pavements.

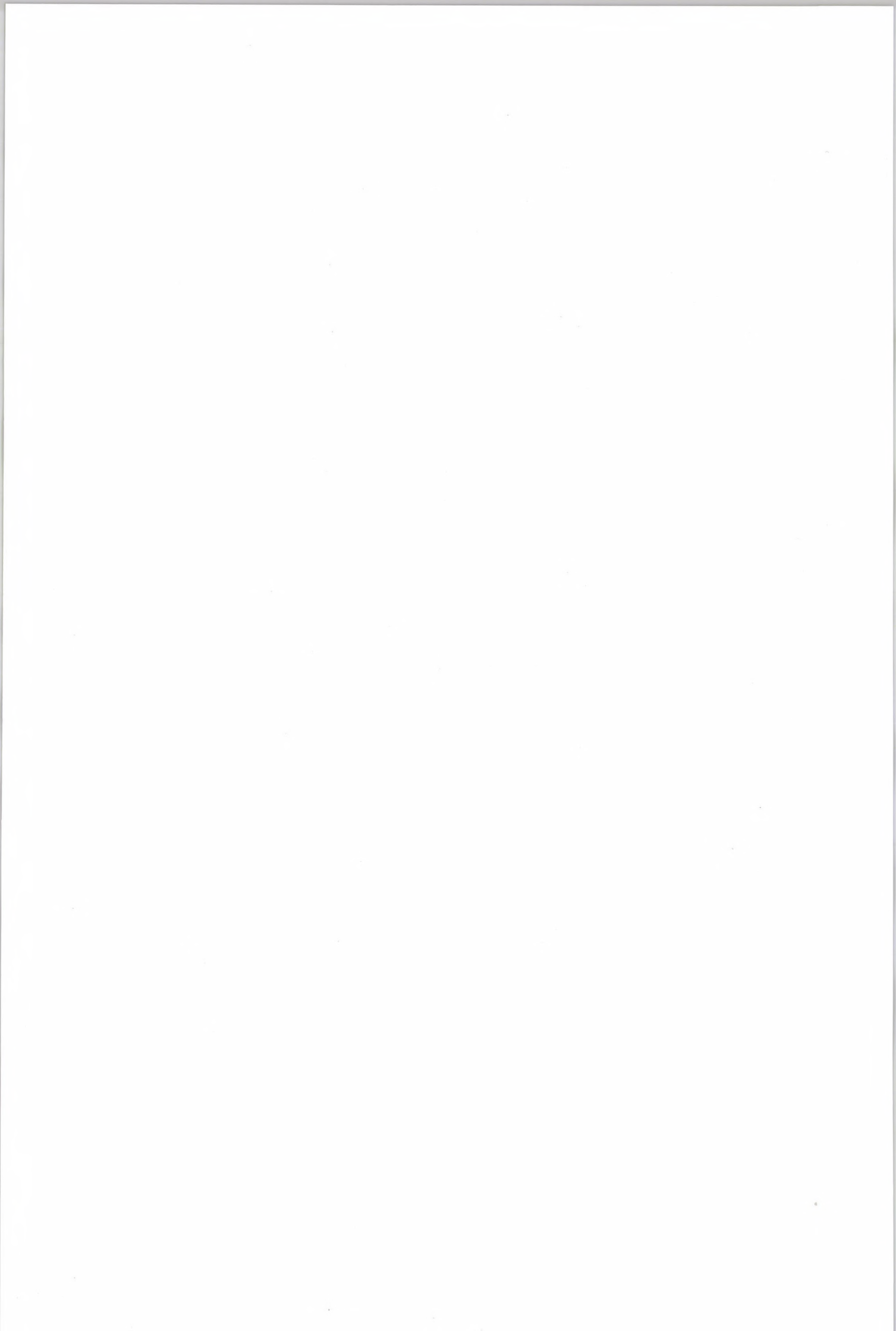
The summer period included a long weekend with a national holiday. During the weekend the elemental concentrations and also the total mass decreased, and in the beginning of the following week it started to increase.

Size distribution: the impactor we have used separate the aerosol within the size range of 0.25 μm and 30 μm into 7 fractions. The mass size distribution for elements of natural origin, like Si, Ca, Ti, Fe, and Mn has one mode: the coarse mode. The peak appeared in the 8–16 μm and in the 16–30 μm size fraction. The size distribution of these was very similar in both periods, although in summer there is a tendency towards smaller aerodynamic diameters. The mass size distribution of the elements S, K, Cl, Zn, Cu has two modes: one peak occurs between 0.25 and 0.5 μm , the coarse particles has a peak around 16 μm . Usually an indication of a third peak appears in the 1–2 μm size fraction. This can be mainly observed in the samples collected in the winter period. In the case of Cl we observed a coarse and a condensation peak in winter, in summer only a condensation peak appeared. The distribution of K has a bimodal shape (originates from biomass burning and

from soil), but there is no significant difference between the summer and winter concentrations, on the contrary as it should have been expected.

This is a preliminary study, we plan to carry on campaign samplings with the PCI, and usual sampling with the streaker sampler.

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Biological and Medical Researches

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Preparation of [^{123}I] β -CIT for Receptor Studies

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The β -CIT (2 β -carbomethoxy-3 β -(4-iodophenyl)tropane) is a proved marker of both dopamine transporters in the striatum and serotonin transporters in the hypothalamic region of the brain [1] and can be used for the diagnosis of several neuropsychiatric disorders. Both the ^{123}I and the ^{11}C labeled β -CIT was developed for SPECT and PET investigations some years ago [2, 3, 4, 5, 6]. The integrity of the presynaptic nigrostriatal dopaminergic projection can be studied in vivo with β -CIT what means that this radiopharmaceutical can play important role in clinical investigation of patients with parkinsonism. Here we describe a modified synthesis of [^{123}I] β -CIT.

The ^{123}I was prepared by $^{123}\text{Te}(p,n)$ reaction on the MGC-20 compact cyclotron. The product was separated from the target by dry distillation and was trapped in a 0.002 M NaOH solution. Iodogen (1,3,4,6-tetrachloro-3 α -6 β -diphenylglycouril) solution was freshly prepared just before the labeling: 4.7 mg Iodogen (Sigma) was dissolved in 600 μl ethanol and the suspension was filtered through 0.22 μm filter (MillexGV). 25 μg of dry precursor (trimethylstannyl- β -CT, Research Biochemicals Incorporated) was dissolved in 50 μl absolute ethanol in a reaction vial. 100 μl Iodogen solution and 100 μl 0.1 N H_3PO_4 was subsequently added. 15 mCi of 200 μl (no carrier added) ^{123}I solution was transferred into the reaction vial. According to preliminary experiments the pH value of the reaction mixture has to be around 3.0. The pH was adjusted with paper indicator of 0.5 unit steps; for the adjustment finally 250 μl 0.002 M NaOH and 70 μl 0.1 N H_3PO_4 was used. The quick pH adjustment seemed to be essential. The reaction vial was then kept at room temperature in dark for 20 minutes.

Sep-Pak C-18 (Waters) cartridge was preliminary treated by washing with 5 ml ethanol and subsequently with 10 ml of water. The reaction mixture was transferred from the reaction vial to the cartridge. The Sep-Pak was then washed with 10 ml of water. The [^{123}I] β -CIT was eluted with 2 ml of 1:1 0.1 M H_3PO_4 :ethanol. The solution was filtered through 0.22 μm filter (MillexGV). The total synthesis time including purification was 50 minutes. The quality control was carried out from this filtered solution.

The HPLC system was coupled with NaI gamma detector and UV detector (220 nm) with computer data evaluation. The analysis of [^{123}I] β -CIT was carried out on a Lichrosorb RP-18 column (250 mm) using methanol:water:(Et) $_3$ N buffer 75:25:0.2 v/v mobile phase. The reference β -CIT standard (in D-tartrate form), used for identification of the radiocompound, was obtained from MAP Medical Technology, Finland. Under the above circumstances the retention time of [^{123}I] β -CIT was 10.5 min at a flow rate of 1.2 ml/min. The HPLC chromatogram is shown in the Fig. 1.

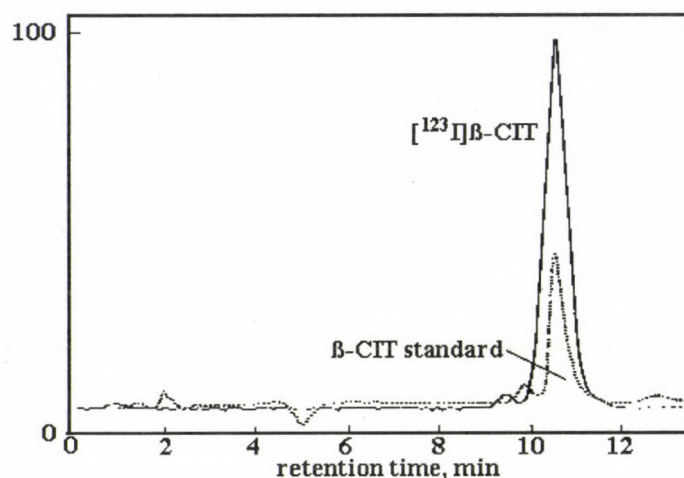


Fig. 1: HPLC chromatogram of [^{123}I] β -CIT

The final product was 10.6 mCi at the end of production that corresponds to 72% chemical yield (decay corrected). The radiochemical purity was 96%.

This work was supported by ETT 107/97 contract.

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Selective Oxidation of ^{11}C -Methane to ^{11}C -Methanol over Iron-Zeolite Catalyst

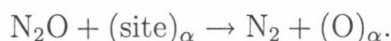
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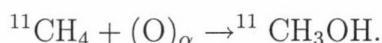
Last years, in surface science, several papers appeared on the selective oxidation of methane to methanol using Fe/ZSM-5 zeolite as catalyst. On the basis of these results we investigated this process to produce from ^{11}C -methane to ^{11}C -methanol. Our direct aim was to develop a simpler, one step reaction method by iron-zeolite catalyst as compared to known methods. The ^{11}C -methanol is an important intermediate for the synthesis of ^{11}C -methyl iodide and subsequently ^{11}C -methylation. The ^{11}C -methanol can be even itself a methylate reagent in several cases but only with catalyst. ^{11}C -labelled radiopharmaceuticals are used for investigation of positron emission tomography.

In addition to production of ^{11}C -radiopharmaceuticals, research on the mechanism of the catalysis by radiodetection adds more information to the research of natural methane monooxygenase. The Fe-containing enzyme catalyst is mimicked by Fe/ZSM-5 zeolite which can stoichiometric, selectively oxidize methane to methanol. In the other hand, in the chemical industry, the research on the stoichiometric conversion of methane to methanol by this simple method is in prominent position, because of large natural deposits of methane.

The Fe/ZSM-5 zeolite catalyst was prepared in Department of Inorganic Chemistry of Utrecht University. At partial oxidation of ^{11}C -methane the first step was to produce oxygen on the catalyst at 250 °C:



Here (site) is a special surface site of Fe/ZSM-5 zeolite where the oxygen from decomposition of N_2O is adsorbed peculiarly (named-form). After cooling the catalyst to 50 °C, the reactivity of $(\text{O})_\alpha$ coordinated to the binuclear Fe-containing site of Fe/ZSM-5 zeolite is enough high to insert into ^{11}C -methane molecule:



The synthesis works at room temperature already. The ^{11}C -methane was concentrated in small volume before injection to the catalyst. After synthesis the products were analysed by radio-gas chromatography. It is known that ^{11}C -methanol can not desorb (but ^{11}C -carbon monoxide and ^{11}C -carbon dioxide yes) at even higher temperature without change from catalyst so it was identified by indirect way warming up to 290 °C. The ^{11}C -methanol was desorbed and changed suddenly to ^{11}C -carbon monoxide and ^{11}C -carbon dioxide. The yield of ^{11}C -methanol was calculated from these changed products.

Summarizing our initial experiments we were able to synthesize ^{11}C -methanol by iron-zeolite catalyst but with low yield. Our aim in future to determine the optimal parameters for high yield.

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Development of Methods and Instruments

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Suppression of Low Energy Background by Rise-Time Discrimination in Silicon Drift Detector

G. Kalinka, J. Gál and Zs. Kertész

Best Si(Li) and HP Si detectors possess high quality, thin metal Schottky-barrier (SB) entrance windows. Due to the high electric field and low surface recombination, the charge collection efficiency (CCE) for thermalized carriers in these detectors is rather high even in the vicinity of the SB. Thus, for low energy X-rays the background continuum (BC) is related mostly to energetic electrons created in the primary interaction of the detector material with the incident X-rays, through escaping out of detector volume into SB layer, and vice versa. These processes result in more or less flat BC with steps at characteristic detector and SB material energies [1]. Typical BC to peak height ratios (B/P) for 6 keV X-rays are 1/10000 and 1/30000 above and below SiK edge.

Best pn junction entrance window silicon detectors have to date somewhat inferior B/P performance [2]. In these type of detectors, and lower quality SB Si(Li) detectors, as well, there is an incomplete charge collection (ICC) layer in which the CCE is significantly lower than unity. Such an ICC region will, necessarily, increase background, by spreading events according to CCE amplitude range within ICC.

The exact shape of BC will depend on the particular CCE depth function. While the effect of a "thin" ICC region is a mere increase of the BC with some extra "rounding" of the characteristic steps beyond Fano statistics, in the case of a "thick" ICC region with linear CCE dependence from 0 to 1, the BC will be high and flat, with no characteristic structures at all.

Since it is expected that collection of charge carriers from an ICC region may cause certain time delay, this fact can, at least in principle, be utilized for discriminating against such events. An early experiment [3] was, however, unable to resolve such tiny time lags at 6 keV. Unlike Si(Li) detectors, having extremely long (up to, or even above 0.1 ms) noise corner time constants, for SDDs, thanks to their extremely low capacitance (cca. 0.1 pF), it is below 1 ms, i.e. much closer to charge collection time (cca. 100 ns). The related lower jitter makes timing much more accurate, and rise-time discrimination (RTD) more promising.

In a recent experiment with a KETEK SDD of cca. 2.5 mm diameter we have succeeded in getting a significant BC reduction at 6 keV incident energy. Without discrimination the BC was almost flat, with a B/P ratio of 1/800. Using RTD [4], this value decreased to 1/2000 above, and 1/3000 below SiK edge energy. Collimating MnK X-rays to diameter 1mm in the center of SDD the improvement is more pronounced: the B/P ratios are 1/7000 and 1/17000 in corresponding regions. This means, that timing is rather critical: even small spatial- and related time-broadening [5] of electron packets during their collection from peripheral regions strongly diminishes efficient RTD.

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strongly diminishes efficient RTD. This means that timing is rather critical: even small spatial- and related time-problems [5] of electron packets during their collection from peripheral regions more pronounced: the B/P ratios are 1/7000 and 1/17000 in corresponding regions. Making X-rays to diameter 1mm in the center of SDD the improvement is this value decreased to 1/2000 above, and 1/3000 below 20keV edge energy. Collimation the BC was almost flat, with a B/P ratio of 1/800. Using RTD [4] succeeded in getting a significant BC reduction at 6 keV incident energy. Without In a recent experiment with a KETEK SDD of ca. 2.5 mm diameter we have accurate, and rise-time discrimination (RTD) more promising.

High-Resolution PIXE Instrumentation survey. Part IV.

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In the present fourth part we updated data about sites, which were formerly discussed in the first three parts [1, 2, 3]. According to the changes in the world (new states, new addresses, spreading of the electronic mail, etc.) additional data were given, and newer papers (30) from the formerly discussed sites were placed into our bibliography. Because of the large amount of updating data we did not involve new sites continuing our Table 1.

The paper was presented at the Third International Symposium on Bio-PIXE (Nov. 16–19, 1999, Kyoto, Japan) as an oral presentation, and as a poster. It was submitted to the International Journal of PIXE, to be published in the symposium's proceedings. It has been accepted for publication.

The oral presentation emphasized the power of newer high-resolution/high-luminosity crystal spectrometers making possible to measure satellite spectra of medium and high Z elements, and even the very weak $K^2\beta L^i$ hypersatellites. Such weak lines, as the $K\beta_5$ or the multiple ionization KL satellites in some cases must be considered in the evaluation of PIXE spectra, obtained by semiconductor detectors (mainly Si(Li)), therefore the results of their compilations [4, 5, 6] were involved into the newer versions of the well known GUPIX PIXE evaluation program [7]. These are good examples of the help of crystal spectrometer people to PIXE people.

The work was supported partly by OTKA No. T016636 and in part by RFFI under Grants No. 98-02-17238 and No. 99-02-16357. I.T. thanks the OMFB for supporting the travel to the symposium (contract No. 01878/99).

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New Monte Carlo Code for the Study of the Response Function of Si(Li) Detectors for X Rays

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It is generally recognized that the Monte Carlo simulation is very useful tool to understand the lineshape of X-ray spectrum with a Si(Li) detector. We have developed a new Monte Carlo code and tested it to simulate the response function of the Si(Li) detectors in the range of primary X-ray energy less than 5 keV. The present Monte Carlo code differs from the well known Monte Carlo codes developed earlier. In our simulation we took into account the elastic and sum of the inelastic processes of produced electrons in the solid as well as the charge collection probabilities in the different region of Si(Li). The Monte Carlo simulation, applied here, was based on the application of the dielectric function formalism. The partial expansion method was used to describe the differential and total cross sections for elastic scattering using the code described in Ref. [1]. Following [2] the dielectric function was described in terms of a sum of Drude-type functions. In this simulation model of the frequency and wavenumber dependent energy loss function, all inelastic processes are automatically include which electrons undergo.

For the detector model we used the same model as described in Ref. [3]. The detector is divided into four different part and is assumed to have a gold entrance window of thickness d_w , a silicon dead layer of thickness d_d , a partial sensitive layer of silicon of thickness d_{ps} and a silicon sensitive layer of thickness d_s . For the entrance window and the dead layer of silicon have a charge collection efficiency $\eta = 0$, for the partial sensitive silicon layer $0 < \eta < 1$ and for the sensitive layer $\eta = 1$, respectively.

As our preliminary results to demonstrate the validity of the approximations used in the present code, the calculation of the response function of Si(Li) detectors, using the same parameter as described in Ref. [3]. was performed and the obtained results were compared with the simulated data in Ref. [3]. It has been confirmed that our calculations are in good agreement with the results of Geretschläger.

This work was performed under the Japanese–Hungarian Cooperative Research Project. The work was also supported by the Hungarian Scientific Research Fund: OTKA No. F022059.

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Investigation of 3D Activity Distribution of Positron Emitter Isotopes by Using Coincidence Spectroscopy

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In the framework of our JSPS-HAS co-operation project the experimental establishment of 3D imaging of industrial samples by using positron emission tomography has been investigated at the Department of Quantum Science and Energy Engineering of the Tohoku University. The study of static and dynamic processes was especially emphasized.

An experimental arrangement was designed by using the existing equipment of the Tohoku University Radioisotope Center, which required only limited new investment and mechanical work. The purpose of the experiment was to make a 3D image of a spatial radioactive object, in order to investigate the spatial distribution of the radioactive material in the object both in static and also in dynamic conditions. For this purpose the coincidence timing technique, based on NaI(Tl) scintillation detectors was used. The detectors were mounted on the goniometer table. 1 mm × 1 mm lead collimators (5 cm long), manufactured in the workshop of the university were also mounted between the sample holder and the detectors. The detector-collimator alignment was checked and adjusted by using laser beam. The sample itself was mounted between the both collimators on a linear/rotation stage. The timing spectrometer was assembled from NIM modules and a PC based multichannel analyzer. The system was optimized for a time resolution of approximately 5 nanoseconds.

As test sample a plastic tube filled with approximately 8 mCi of ^{18}F isotope, provided by the Tohoku Radioisotope Center was used. The initial activity and the half-life of the ^{18}F beta emitter made possible to continue the measurements approximately 10 hours. The sample was mounted horizontally, approximately in the center of the arrangement. The time spectra were collected in 10 linear positions from 4 directions in each position. A second series of measurement was also performed by turning the sample in vertical position. The data collected were used to reconstruct the images by using the special enhancement code developed in the Department of Quantum Science and Energy Engineering for evaluation and enhancement of 3D PET images.

Research and Application of the ECR Ion Source

S. Biri, A. Valek, F. Ditrói, L. Kenéz, Cs. Szabó

Instrument and beam development. The magnetic mirror ratio of the ECR Ion Source was increased from 1.8 to 2.2 at the injection side. The length of the plasma chamber (and thus, the plasma volume) has been optimized and the vacuum pumping efficiency was increased. Using a simulation software the extraction optics system has been improved. The water cooling system was modified and now it can be operated at any weather conditions. All these developments resulted in an increase of the heavy ion beam currents by a factor of $1.5 \div 10$. Figure 1 shows the highest beam currents obtained from the ATOMKI-ECRIS so far. Most extractions were carried out at 10 kV platform potential.

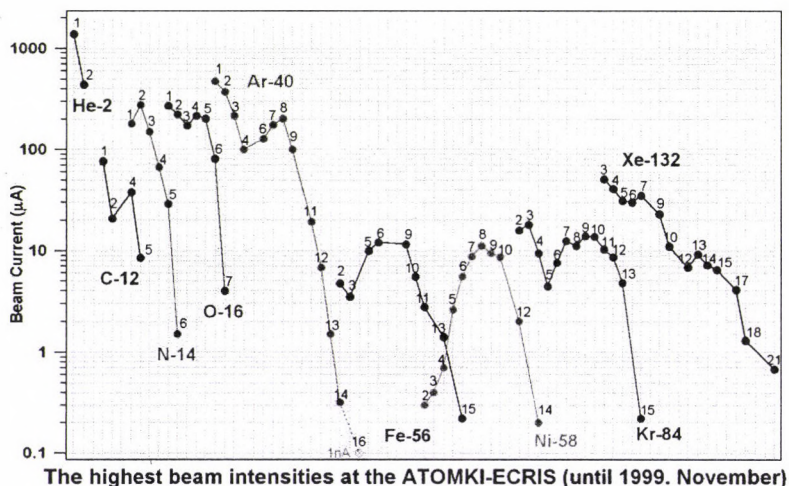


Fig. 1: The highest beam currents obtained from the ATOMKI-ECRIS

Plasma research. Two accompanying papers [1] describe some results on plasma physics research carried out in our lab in 1999. A new project (implantation of N ions into fullerene molecules) will start in 2000.

Material research with highly charged heavy ions. At the Frankfurt ECR-RFQ complex. Ar ions with energies of $6 \div 8$ MeV and with charge states of 8, 12 and higher were used to irradiate thin (1–2 micrometer) Si crystals. By measuring the transmitted and post-accelerated particles we investigated the modification in average charge state and charge state distribution after passing through the sample.

We continued our other collaborations with foreign ECR groups. Promising experiments were carried out in the NIRS institute (Japan) while for the PSI (Switzerland) pionic hydrogen project an ECR Ion Trap was designed. New results are expected in 2000.

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ECR Plasma Diagnostics with Langmuir Probe

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An Electron Cyclotron Resonance (ECR) Ion Source is a tool to generate highly charged ions. The ion beam is extracted from the plasma chamber of the ECRIS. Higher charge states and beam intensities are the main objectives of ECR research. The heart of an ion source is the confined plasma which should be well known to reach those objectives. Information about the plasma can be obtained by plasma diagnostics methods. Langmuir probes were successfully used in case of other plasmas, e.g. TOKAMAK.

Until last year plasma diagnostics at the ATOMKI ECRIS was performed by X-ray and visible light measurements. While X-ray measurements give global information, the Langmuir probe method can give information on the local plasma parameters. This is an advantage because the local parameters are not known in detail. By Langmuir probe measurements it is possible to get information on plasma density, plasma potential and partly on the electron temperature.

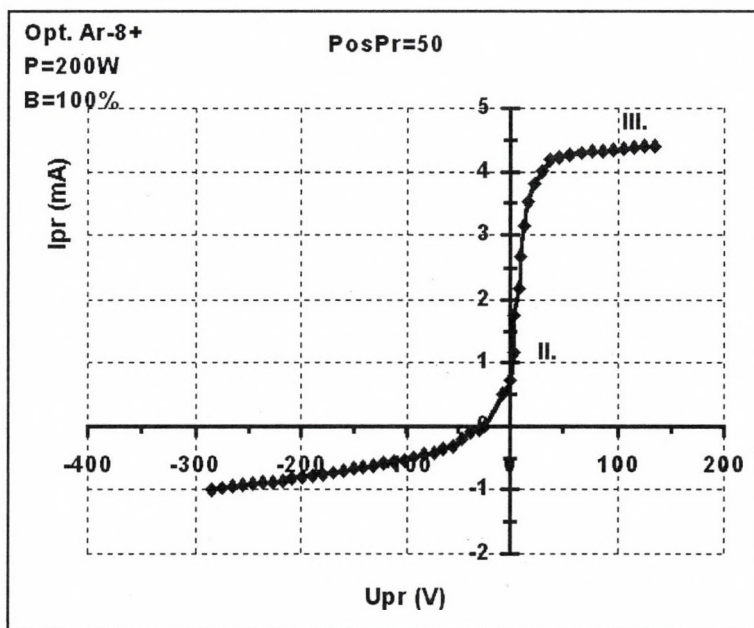


Fig. 1: A typical $U-I$ curve. I: ion saturation current region, III: electron saturation current region, II: the transition region between them.

From the experimental point of view a Langmuir probe is very simple. However, the precise positioning of the probe in the plasma chamber (HV platform, strong magnetic field, RF waves) is a difficult task. Also the theory of probes is

complicated: the ECR plasma is a special one because the confining magnetic field is inhomogeneous, beside hot electrons it contains cold ions with different charge states and it is heated with high frequency EM waves.

What can be measured with a probe is a voltage-current ($U-I$) characteristics. Figure 1 shows a typical $U-I$ curve measured in our lab. As it can be seen in the figure the diagram has three main parts. An ion saturation current region (I.), an electron saturation current region (III.) and a transition region (II.) between them. These measurements were performed using two different power supplies to bias the probe to positive and negative voltage.

To perform more precise $U-I$ measurements we need a special power supply which is presently being built in the ATOMKI. The specialty of this power supply is that we will continuously control the bias voltage of the probe from -500 V to $+500$ V with 0.1 V accuracy. Also we can simultaneously measure the electron and ion currents with 0.01 mA accuracy. We designed a new mechanism which will enable us to scan the whole volume of the plasma chamber. One of our plans for the future is to apply this probe to explain the effect of external electron injection into the plasma.

Ion Beam Dose Measurement in Nuclear Microprobe Using a Compact Beam Chopper

L. Bartha and I. U: onyi

The accurate measurement of ion beam dose is a key point of quantitative analytical methods like PIGE, PIXE or RBS. As all of these analytical work running in our Scanning Nuclear Microprobe are carried out both on insulating and conducting material samples, it was desirable to develop an arrangement, which is not sensitive to the conductivity of samples, furthermore, is applicable in the actual grounded analytical chamber.

To avoid difficulties with current/charge measurement directly on the sample, the beam intensity is measured within better conditions, before it reaches the specimen. In this case a spinning conductor component periodically interrupts the beam before the target, allowing sampling of the ion dose for a constant fraction, usually 10% or less, of the full measurement time. Sampling is carried out by the collection of signals (backscattered particles, X-rays, etc.) induced by the incident particles on the spinning component, which is proportional to the dose. Calibrating the arrangement, the specimen is replaced by a biased Faraday cup. Though, adopting these ideas, several types of so called beam chopper systems have been announced [1, 2, 3], our solution [4] has some advantageous features compared to them:

1. It is placed on the beam axis, inside the measuring chamber, so its presence does not require any modifications and readjustments on the high precision quadrupole lenses.

2. The original arrangement of detectors, sample holders, etc. could remain unchanged after built-in.

3. While others are using continuously rotating chopper wings, we applied a stepper motor to assure rapid change between the on and off states of the ion beam. In addition, an inhibit signal is derived by an electronic controller unit when the wings stop the beam, practically eliminating the detection of background radiation induced in the wing.

4. The backscattered particles emerging from the wings are detected by an annular Si detector, which is protected with a thin Al foil against visible light coming from optical fluorescence of the target or operating light sources inside the chamber.

5. To avoid extremely high or low counting rates for the annular detector, instead of collimating it, changeable wings covered by different scattering materials such as Al, Ni and Au are used.

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Building a New Control System for the Cyclotron Power Supplies

Z. Kormány, T. Lakatos, P. Kovács, I. Szűcs and I. Ander

The MGC cyclotron of the ATOMKI is a multi-particle and variable-energy machine with a rather complicated beam transport system. As a consequence, the current or voltage value of numerous power supplies should be set and adjusted by the operators during a typical run. The original control system of the cyclotron provides a traditional control desk for this purpose where the requested values can be set by using selector switches and up/down tumblers.

The adjustment process with this system is completely manual and rather slow — every power supply unit gets its starting value one after the other and it typically takes 10 to 20 minutes to change the whole setting. Another disadvantage of the present system is the poor reproducibility — the analogue panel meters of the control desk cannot provide the required precision to exactly repeat a former setting.

To overcome the above difficulties and speed up the adjustment process of the cyclotron and the beam transport lines, a new control system for the power supplies has been designed and is under implementation within the framework of our modernization project.* The control of the power supplies will be changed to digital — the analogue control signals of the power stages will be produced by the D/A, the current and voltage values will be read by the A/D conversion modules of a programmable logic controller (PLC).

The transition to digital control requires the development of special interface units. To separate completely the control and measuring channels from each other, they are isolated from the PLC-ground by applying opto-isolators. A two-channel (control and measurement) linear interface circuit built around the TIL 300 optical isolators has been designed, assembled and tested. It has been verified that the linearity and the precision of this circuit fulfills the requirement of all power supplies and allows for its general application in the system.

The digital control of the power supplies requires adjustment elements of new type, which can be connected to any D/A channel and allow easy and convenient value setting. One of the best suited device for this task is the optical shaft encoder. A new adjustment unit with two shaft encoders has been designed, manufactured and assembled. Its interface circuit to the interrupt module of the PLC-station has been built and the assembly code for linking the selected power supply to the encoder and changing the control value by its movement has been developed as well.

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Activities at the Van de Graaff Accelerator Laboratory

L. Bartha and E. Somorjai

During 1999 the beam time of the VdG-1 machine was not significant. The hollow-cathode ion source produced H^- and H^+ ions on the main beam line in 18 hours estimated beam time. These particles were used for low energy atomic physics experiments.

The 5 MV Van de Graaff machine was operating for 2230 hours during this period. Protons (86.8 %), $^4He^+$ (10.2 %) $^{12}C^+$ (2.2 %) and $^{16}O^+$ (0.8%) were accelerated.

The beam time was distributed among different research subjects and education (laboratory practices for undergraduate and Ph.D. students) as it is shown in Table 1.

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

Subject	Hours	%
Atomic physics	192	8.6
Nuclear physics	695	31.2
Analytical studies	72	3.2
Analytics on the microprobe	1173	52.6
Education	93	4.2
Machine tests	5	0.2
Total	2230	100.0

Improvements

In co-operation with the Cryogenics Group, a new, high-purity nitrogen supply line has been constructed by the extension of the former He recuperation piping of the SMS (Superconducting Magnetic Spectrometer), assuring both N and He gas transport, alternatively. Such a way the otherwise lost nitrogen vapour of the liquid nitrogen container can provide the complete quantity of high purity nitrogen gas requirement of our accelerators.

Status Report on the Cyclotron

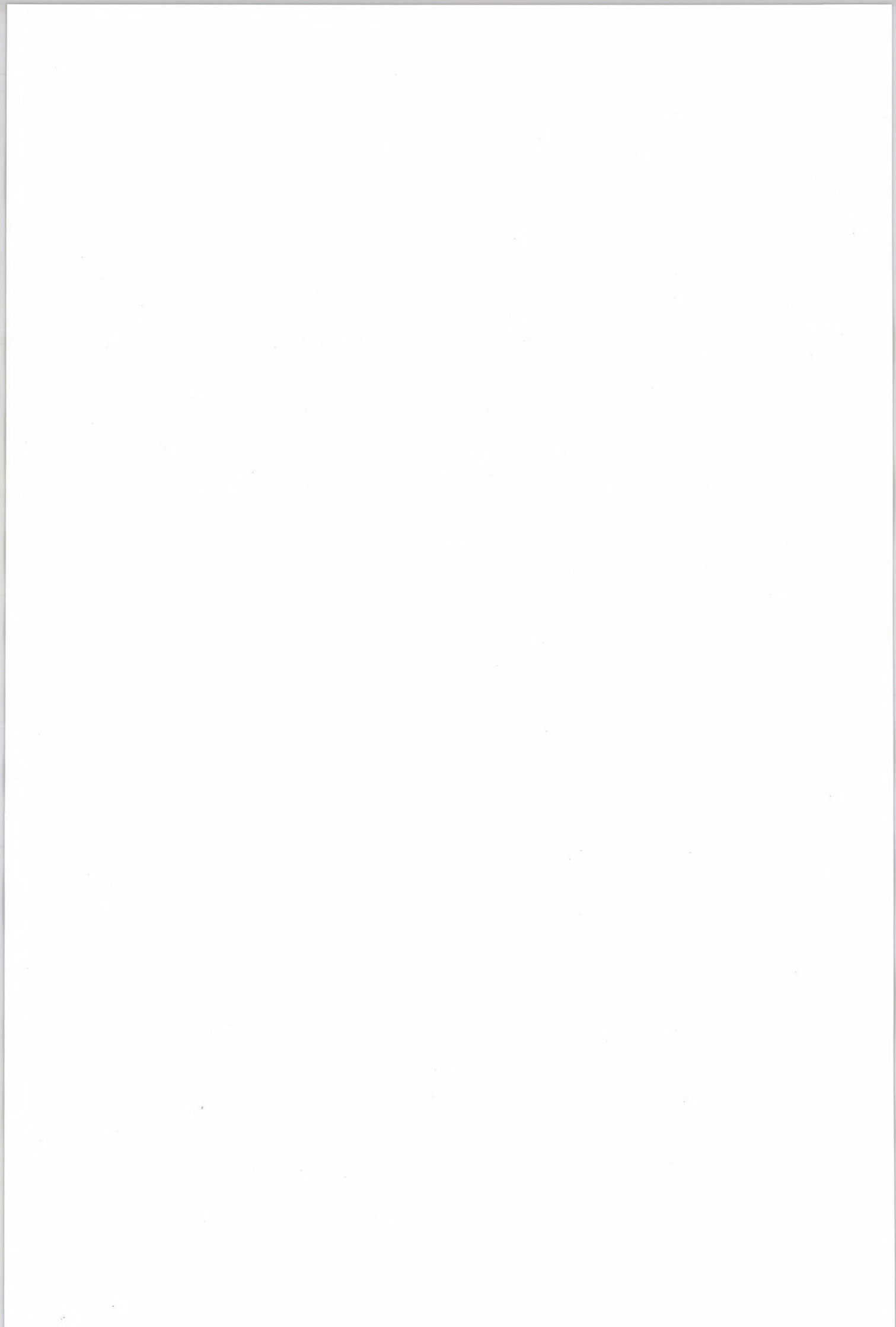
Z. Kormány

The operation of the cyclotron in 1999 was concentrated to the usual 9 months; January, July and August were reserved for maintenance and holidays. The overall working time of the accelerator was 4265 hours, the breakdown periods amounted to 76 hours last year. The cyclotron was available for users during 3888 hours, the effectively used beam time is summarized in Table 1. (FERMI: Front-End Readout Microsystems, Radiation hardness measurements, CERN RD-16). The time used for machine setup and beam tuning or waiting for the start of an irradiation totalled to 546 hours.

The modernization of the vacuum and control systems of the cyclotron — within the framework of a Technical Assistance Program (HUN/4/013) of the International Atomic Energy Agency — has been carried on. The renewal of the gas supply system was completed in the winter maintenance period. It included the replacement of the manual valves with high pressure solenoid valves and the installation of a Tylan FC-280A mass flow controller to set and change the amount of gas flow into the ion source. All the new elements have been connected to the PLC-station dedicated to the control of the vacuum subsystems. The control code, which provides automated gas change processes and allows for very precise regulation of the gas inlet, has been developed as well. As a result, the time to change the working gas in the ion source has been significantly decreased (by a factor of 5 to 10) — the process is completely automated now and does not require any manual or local control from the operator.

Table 1: Distribution of the irradiation (beam on target) time

Projects	Beam time (hours)	%
Nuclear spectroscopy	190	11
Nuclear astrophysics	813	45
FERMI	191	11
Nuclear data	42	2
Neutron physics	11	1
Isotope production	545	30
Total	1792	100



Publications and Seminars

Papers Published in 1999	83
Conference Contributions, Talks, Reports	103
Theses Completed	131
Seminars	132
Author Index	135

Papers Published in 1999

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Candidate of Science Degree (Academic)

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Seminars in 1999

January 14

On the EU 5 Framework Program

A. Zsigmond (OMFB)

January 21

New results and possibilities in the digital processing of detector signals

T. Lakatos

January 28

Band terminations in the Ru and Rh nuclei around $A=100$

J. Timár

February 4

Nuclear fission and symmetry

J. Cseh

February 18

Atmospheric aerosols and they role in the change of global climate and environment

I. Borbély-Kiss

February 25

Super- and hyper-deformation in transuranium nuclei

M. Hunyadi

March 4

History of the concept of physical laws

Gh. Stratan (Bucharest)

March 8

Interpretation of quantum mechanics

P.E. Hodgson

March 9

Arguments and evidence against the Yukawa concept of the nuclear force

V. I. Kukulin (Moscow)

April 8

^{110}Te the $N=58$ isotone

A. J. Boston (Liverpool)

April 15

Terminating bands in light xenon nuclei

E. S. Paul (Liverpool)

April 22

Multiple scattering of electrons in atomic collisions: experimental realization of 'Fermi-accelerator' B. Sulik

April 29

ECR ion sources in RIKEN and in Japan

T. Nakagawa (Tokyo)

May 13

Heavy-ion cancer therapy with ECR ion sources

A. Kitagawa (Chiba, Japan)

May 20

Interacting boson model for three-body systems

R. Bijker (Mexico)

May 27

HUGIN - a small satellite trying to be intelligent

T. Lindblad, K. Waldemark (Stockholm)

June 22

Development of clustering in neutron-rich nuclei

N. Itagaki (Tokyo)

September 24

Research activities of heavy elements nuclear chemistry in JAERI

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October 21

Application of monitor reactions for the measurement of energy and intensity of proton beams in the energy region $E_p \leq 50$ MeV

F. Szelecsényi

October 28

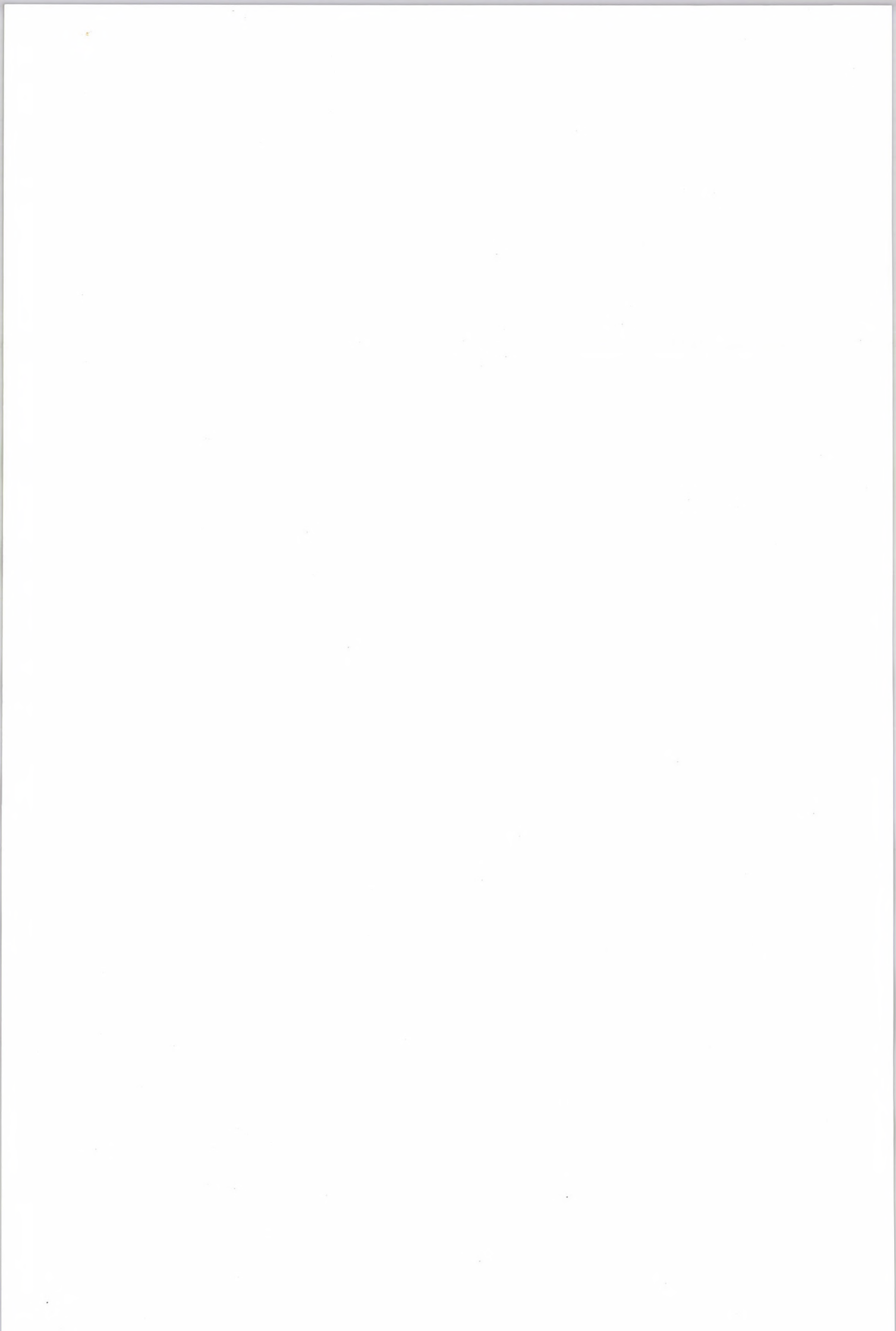
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November 1

Interaction of highly charged ions with microcapillar surfaces

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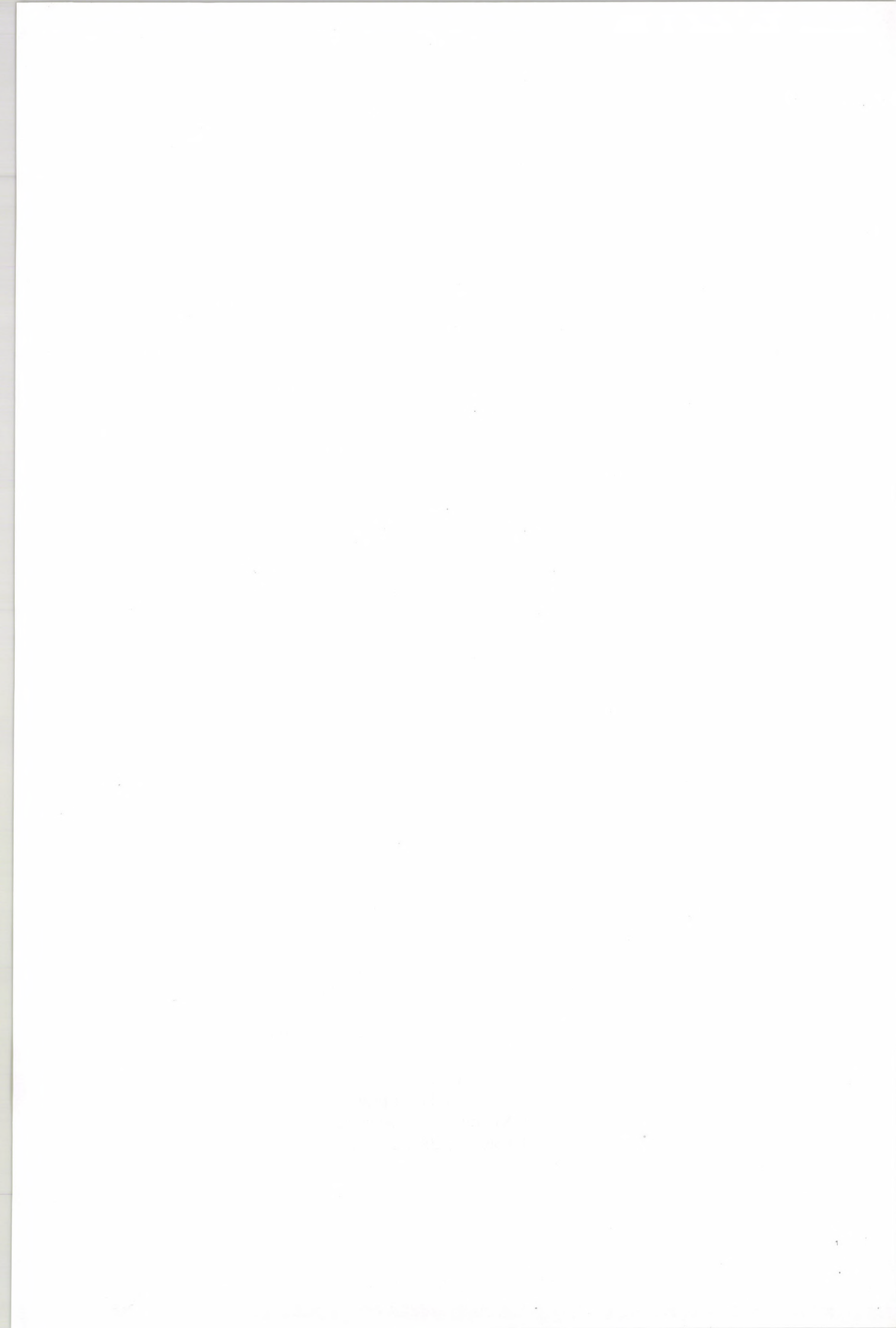
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