ATOMKI
ANNUAL REPORT
1996

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

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ATOMKI

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Hungary

Edited: Z. Gácsi
G. Hock

HU ISSN0 0231-3596

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Preface

For the Hungarian higher education and research establishment, the year 1996 has been the most severe in terms of austerity measures since the change of the political regime in 1989–1990. 1996 brought plunging budget figures as well as slashing cuts on national funds for research and development. Nevertheless, the signs of decline are still not apparent from the indicators of our performance; we still work and publish now and then, and what we do may still be of interest to others. A closer look at our results and comparison with previous years will actually show *enhanced production*. Since it is not entirely impossible that this Annual Report will be read by persons responsible for our funding, it is wise to pre-empt potentially dangerous speculations to the effect that "the less the money the larger the production". Our apparently increased productivity is mostly a result of an even more intensive participation in international co-operation, which is based on funding we had received through an earlier period. Indeed, the number of papers on collaborative works has increased not only because of our joining CERN programs.

Last year's evaluation procedure conducted in the research institutes of the Hungarian Academy of Sciences put this Institute among the better established half of the research institutes, but gave us no reason to be too proud of our achievements. The performance and impact of our basic research (nuclear and atomic physics) were found good, but those of our applied research were not. We explain this finding by pointing out that the evaluation was sensitive to direct scientific impact and to success in making money, but was insensitive to financially non-profitable missions, in which we are supposed to be excellent and indispensable. Hoping that this contention will eventually be accepted, we look forward to the 'stabilization procedure' concluding the evaluation with guarded optimism. We hope to survive and hope to get a more solid budget.

As for our main scientific results dated last year, I would single out the following:

We contributed to understanding cold nuclear fission, which is one of the most interesting discoveries of the 90's in nuclear physics. The cold fission of nuclei may be considered fission because the masses of the two product nuclei are nearly the same; yet cold fission is more similar to cluster decay in that, unlike in usual fission, the product nuclei are brought about in low-energy states. With a group theoretical model of radioactive decay, we interpreted some of the known experimental data and made predictions for further cases of cold fission. The paper that appeared in Journal of Physics G on this subject is one of the most popular papers that appeared in the journal last year. This is known by the recorded number of its downloading by computer sites all over the world.

In the NORDBALL collaboration some members of this Institute took part in the production and spectroscopic study of some nuclei near the exotic "doubly magic" ^{100}Sn.

Another notable result concerns observations of the ionization of target atoms in atomic collisions. Earlier experiments performed in ATOMKI indicated that, despite theoretical considerations, a forward cusp is observable in the electron spectra even in collisions of neutral atoms. With recent experiments we managed to prove that this finding is caused by the projectile's picking up an electron from the target atom temporarily.

It is last year's development that an interference effect between photo-electrons and secondary Auger electrons predicted by a member of this Institute back in 1994 was observed in two independent experiments performed elsewhere.

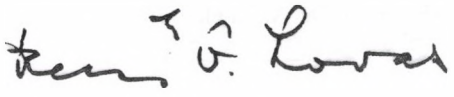
Significant steps were made in isotopic hydrology in model studies of the spreading of potential radioactive contamination in ground water.

Last but not least, it should be mentioned that the construction of the electron-cyclotron-resonance ion source has been virtually completed, and good-quality highly charged heavy ion beams are now available.

Some of the friends of this Institute will be surprised to find that the name under this preface has changed since last year. Well, I can comfort you that Professor Pálinkás, who is still young and vigorous, is well, and retired only from his directorship to devote himself mainly to his pofessorial job at the Department of Experimental Physics, Kossuth University. However, we do not miss him entirely, since he has kept his job as head of the Division of Atomic Physics at this Institute. I took over the directorship from him at the beginning of this year, and I have a three years' appointment. Up to last year, I was one of Prof. Pálinkás's deputy, and last year I was president of the Debrecen University Association as well. I am a nuclear theorist and the first theoretician heading this Institute. My appointment, therefore, must have shaken the foundations of this traditionally experimental institute.

As a final piece of news, I should mention that this Annual Report will be fully accessible through the World-Wide Web at http://www.atomki.hu.

Debrecen, 28 March 1997



Rezső G. Lovas
Director

The organizational structure of ATOMKI

DIRECTOR
Prof. R. G. Lovas

DEPUTY DIRECTORS
Prof. Á. Z. Kiss
Dr. S. Mészáros

FINANCE OFFICER
Dr. M. Pálinkás

SECRETARIAT

INFORMATION SERVICES

SECTION OF ELECTRONICS
headed by Dr. J. Gál

MECHANICAL WORKSHOP
headed by Dr. I. Gál

CYCLOTRON SECTION
headed by Dr. A. Valek

ACCOUNTING

BASIC SERVICES & MAINTENANCE

SCIENTIFIC SECTIONS

DIVISION OF NUCLEAR PHYSICS
headed by Dr. J. Cseh

SECTION OF NUCLEAR SPECTROSCOPY
headed by Dr. A. Krasznahorkay
SECTION OF NUCLEAR PHYSICS
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 PHYSICS
headed by Dr. L. Sarkadi
SECTION OF ELECTRON SPECTROSCOPY
headed by Dr. D. Varga

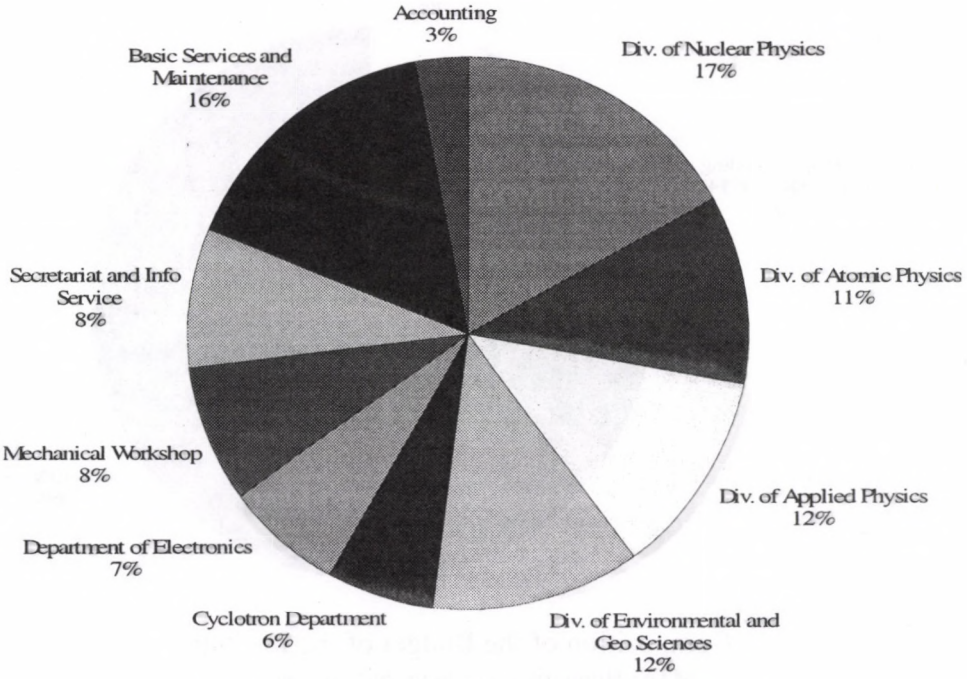
SECTION OF APPLIED PHYSICS
headed by Dr. F. Tárkányi

SECTION OF ENVIRONMENTAL AND EARTH SCIENCES
headed by Dr. E. Hertelendi

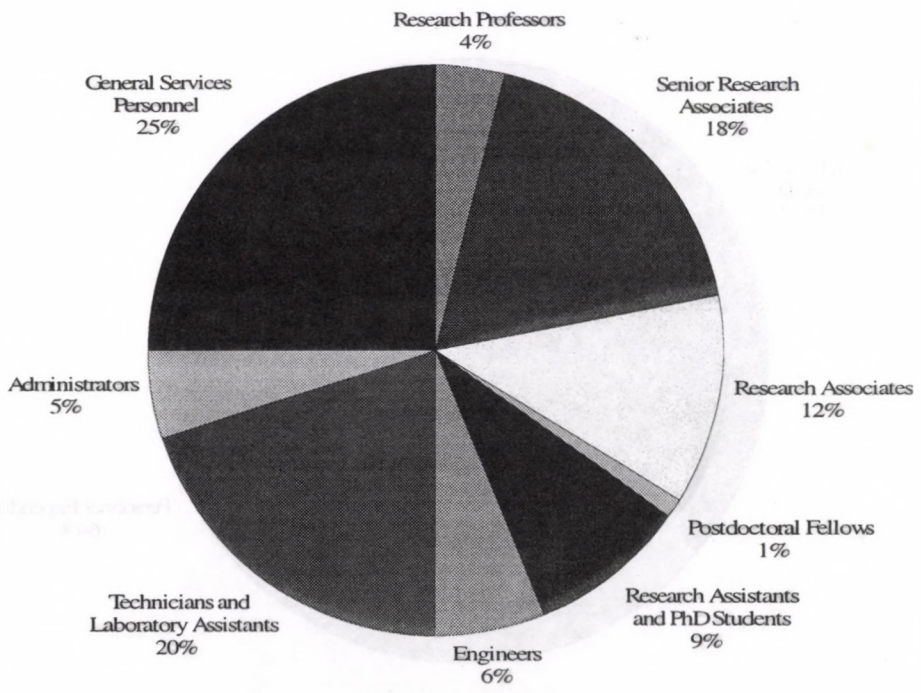
Data on ATOMKI

Personnel

At present the Institute employs a total of 241 persons. The affiliation of personnel to units of organization and the composition of personnel are given below.



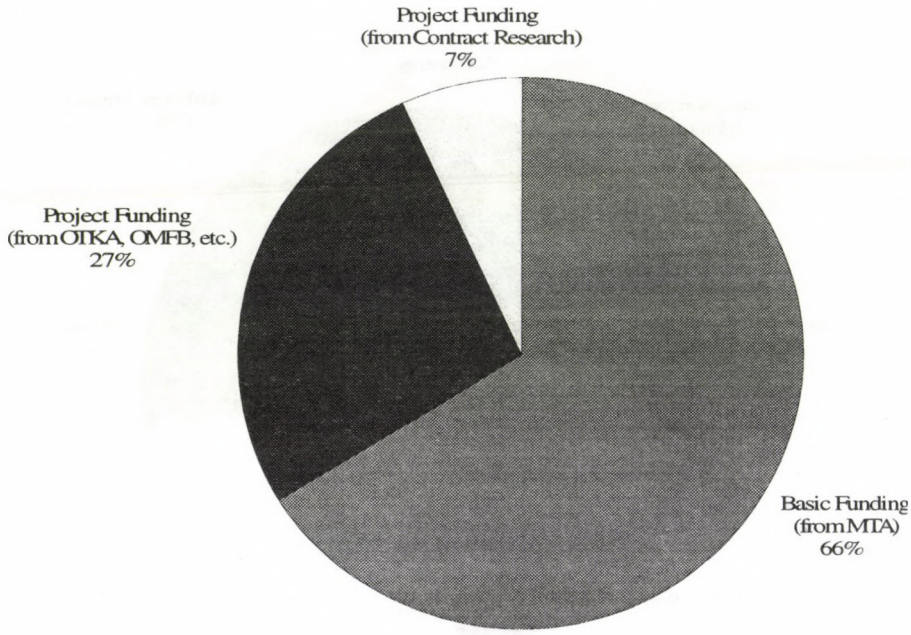
Affiliation of Personnel to Units of Organization



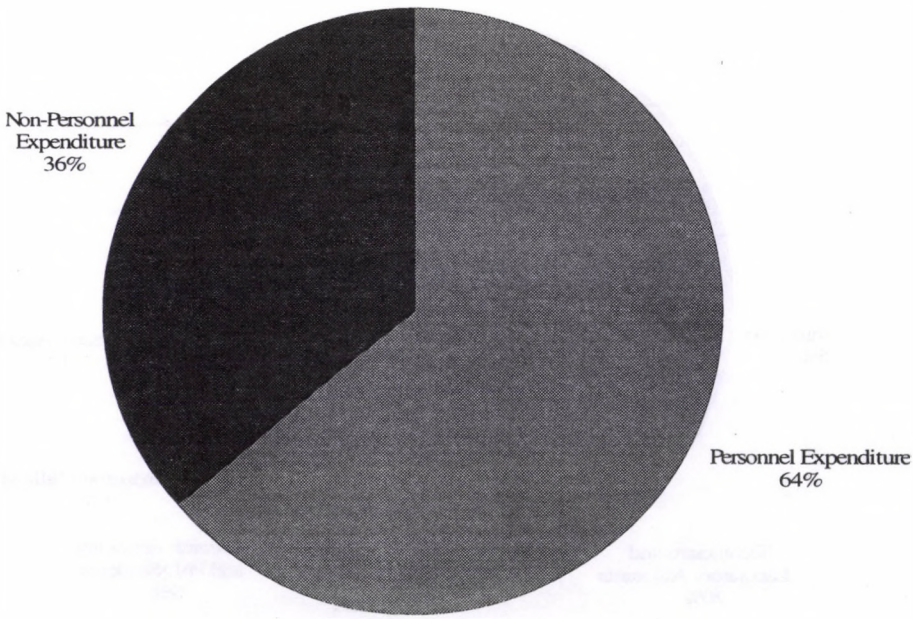
Composition of Personnel

Finance

In 1996 the total budget of the Institute was 291 million Hungarian forints. The composition of the budget and the share of personnel expenditure within the budget are shown below.



Composition of the Budget of the Institute
MTA: Hungarian Academy of Sciences
OTKA: National Fund for Scientific Research
OMFB: National Committee for Technological Development



Breakdown of Expenditure into Personnel and Non-Personnel Expenditure

GENERAL PHYSICS

Quantum Mechanics without 'Measurement'

Z. Máté

It is a well-known dilemma in the present day physics that in spite of the controversial status of the quantummechanical measurement problem the theory itself is perfectly successful. The difficulties caused by this problem appear mainly in the education.

It is suggested in the present work to abandon the concept of measurement in the course of teaching quantum mechanics. The suggestion is based on the statement that 'measurement' is not an essential part of quantum mechanics; the omission of it does not cause any change in the practice of physics.

The verification of such a statement can only be done by analysing many examples. This programme was started in [1] by comparing the language of a concrete nuclear physics experiment [2] with that of the standard textbooks on quantum mechanics and with the spirit of an interesting discussion [3] of Heisenberg and Bohr (Oberaudorf, Germany, 1933).

It should be stressed that the disregard of the concept of measurement does not solve the foundational problems of quantum mechanics; it just reduces the amount of confusing considerations. The solution of contradictions is hoped to be a result of a future consensus of experts working on the fundamental problems of quantum physics.

[1] Z. Máté, *Quantum measurement and practice in nuclear physics*, Proc. of the 2nd Int. Symp. on Fundamental Problems in Quantum Physics, Oviedo, Spain, 21–26 July 1996, Eds. M. Ferrero and A. van der Merwe (Kluwer Academic), in press

[2] A. Krasznahorkay, M. Hunyadi, M. Csatlós, I. Diószegi, J. Gulyás and Z. Máté, 'Evidence for hyperdeformed nuclear shape in $^{236}U^{*}$', *Acta Phys. Pol.* B **27** 139 (1996)

[3] W. Heisenberg, *Physics and beyond* (George Allen and Unwin, London 1971) p. 129

Phase-equivalent potentials from supersymmetry: analytical results

G. Lévai, D. Baye[†] and J.-M. Sparenberg[†]

[†] Université Libre de Bruxelles, Brussels, Belgium

Phase equivalent potentials appear naturally in various branches of physics. Besides having the same phase shifts, these potentials might support different number of bound states if (at least) one of them is singular at the origin. The formalism of supersymmetric quantum mechanics (SUSYQM), an approach to essentially isospectral potentials, was found to be especially suitable to describing phase-equivalent potentials. It has been developed to a stage where, in principle, arbitrary modifications of the energy spectrum are possible [1]. The final potential and the wavefunctions are expressed in terms of the physical and unphysical solutions of the original Schrödinger equation.

The generality and compactness of these formulas raises the question whether one can find examples where the procedure can be performed in an analytical way, i.e. whether there are cases where the resulting potential and its solutions are obtained in closed algebraic expressions. Apart from their aesthetic value, the importance of analytical transformations lies in the fact that exact results can be obtained even in critical conditions, when numerical techniques might not be safely controlled. Handling complex potentials can raise such problems, for example [2].

As a first attempt we considered the generalized Pöschl–Teller potential and derived analytical results for the following types of transformations [3]: *i)* Removing an arbitrary bound state. *ii)* Adding a new bound state at specific energies. *iii)* Removing the first few states. The resulting potentials are expressed in terms of somewhat complicated formulas containing hypergeometric functions. We extended these results to the generalized Ginocchio potential, which contains the generalized Pöschl–Teller potential as a special case and also has a repulsive (r^{-2}-like) singularity at the origin, simulating the centrifugal term [4]. Transformations *i)* and *ii)* are also possible here, however, *iii)* is not, because it is applicable only to shape-invariant potentials. We also derived closed formulas for the transformed wavefunctions and discussed which further potentials might admit transformations *i)*, *ii)* and *iii)* above. Although the examples discussed until now cover only a small fraction of solvable potentials, their shape is close to that of potentials used in the description of realistic physical problems.

This work was supported by the OTKA grant No. F20689.

[1] D. Baye and J.-M. Sparenberg, *Phys. Rev. Lett.* **73** (1994) 2789.
[2] D. Baye, G. Lévai and J.-M. Sparenberg, *Nucl. Phys.* A **599** (1996) 435.
[3] G. Lévai, D. Baye and J.-M. Sparenberg, in *Proc. Int. Conf. on Inverse and Algebraic Quantum Scattering Theory*, Balatonföldvár, Hungary, 3–7 September, 1996, in press.
[4] G. Lévai, D. Baye and J.-M. Sparenberg, in preparation.

NUCLEAR PHYSICS

Lifetime measurements in ^{36}Ar

Gy. Gyürky, Zs. Fülöp, Á.Z. Kiss, E. Somorjai,
A. Kangasmäki,* P. Tikkanen,* J. Keinonen*

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The systematic study of the *sd*-shell nuclei were continued in the framework of a cooperation project between the Laboratories of the Helsinki University and ATOMKI. The goal of the studies was the ^{36}Ar nucleus. Experimental data for ^{36}Ar is lacking, the few known lifetimes of excited states are only poorly determined. There are great discrepancies in the previously reported lifetime values, especially for the short-living states ($\tau < 100$ fs). The present study was undertaken in order to clear the apparent discrepancy in the reported mean lifetime values, and to be able to further test the modern shell model in this mass region.

The ^{35}Cl(p, γ)^{36}Ar radiative capture reaction was used for the measurements. In these reaction studies, the 1.2 to 2.0 MeV proton beam with a typical intensity of 10 μA was supplied by the 5 MV Van de Graaff accelerator of ATOMKI. The ^{35}Cl target was implanted into thick Ta backing.

The gamma-decay of four resonances were studied and their branching ratios were determined [1]. For the lifetime measurements the Doppler shift attenuation (DSA) method was applied using computer simulations with Monte Carlo method and experimental stopping power values. The evaluation of the lifetime values is in progress.

In order to reduce the ^{19}F(p, $\alpha\gamma$)^{16}O background the preparation of new set of implanted targets is under way in Helsinki.

[1] Gy. Gyürky, Zs. Fülöp, Á.Z. Kiss, E. Somorjai, A. Kangasmäki, P. Tikkanen, J. Keinonen, *Proceedings of Ninth International Symposium on Capture Gamma Ray Spectroscopy and Related Topics*, Budapest, 8–12 October 1996, in press.

Spectroscopy of neutron deficient ^{65}Ge

D. Sohler, Zs. Dombrádi, B.M. Nyakó
and the NORDBALL collaboration

The structure of the neutron deficient ^{65}Ge was investigated [1] through the ^{12}C(^{58}Ni, αn) reaction using the NORDBALL multidetector array. The level scheme of ^{65}Ge was significantly extended up to $E_x = 9$ MeV and $J^\pi = (33/2^-)$ on the basis of $\gamma\gamma$-coincidence relations and angular distribution ratios. The proposed level scheme is shown in Fig. 1a.

The states below 3 MeV were described in the framework of the interacting boson–fermion model (IBFM) and interpreted as members of proton–neutron–phonon multiplets. The negative parity levels with $J^\pi \geq 15/2^-$ are expected to have $1\nu 2\pi$ and 3π broken pair configurations. The IBFM energy spectrum is compared with the experimental data in Fig. 1b.

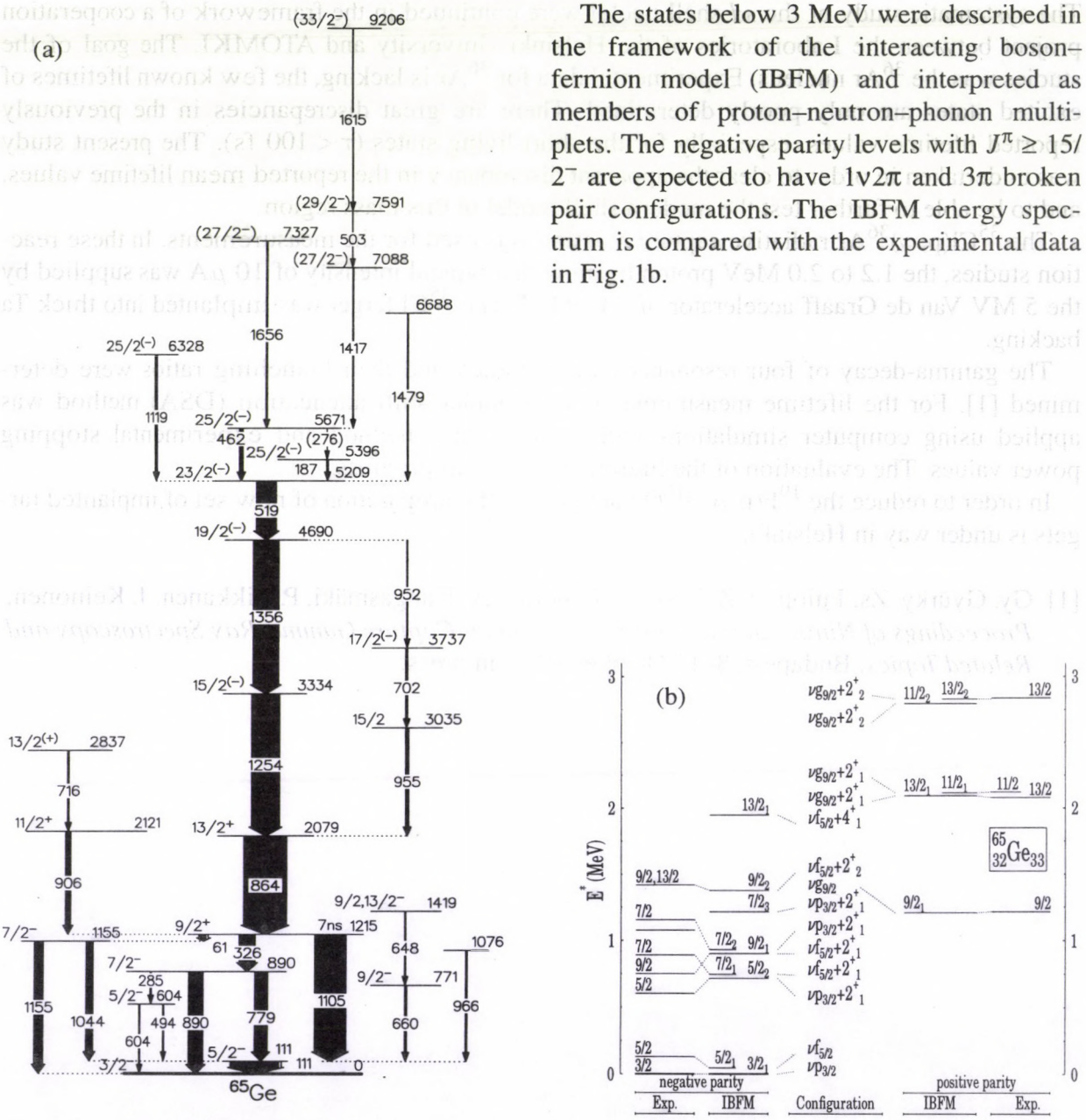

Fig. 1. (a) Proposed level scheme for ^{65}Ge. (b) Calculated low-lying states of ^{65}Ge compared to the experimental data.

[1] D. Sohler *et al.*, *Z. Phys.* A, in print

Spectroscopy of ^{68}As

D. Sohler, Zs. Dombrádi, B.M. Nyakó
and the NORDBALL collaboration

A new level scheme of the ^{68}As, populated via ^{12}C(^{58}Ni, *pn*) reaction, has been constructed up to 6 MeV excitation energy and $J^{\pi} = (15^{+})$. In addition the 2158 keV state a new isomer was found at 1571 keV with a half life of 19±3 ns.

The structure of the low-lying states was discussed with help of the interacting boson–fermion–fermion model (IBFFM). The states below 2.3 MeV were described as members of proton-neutron and proton–neutron–phonon multiplets. The higher-lying states are expected to have broken pair configurations. The IBFFM energy spectrum is compared to the experimental results in Fig. 1.

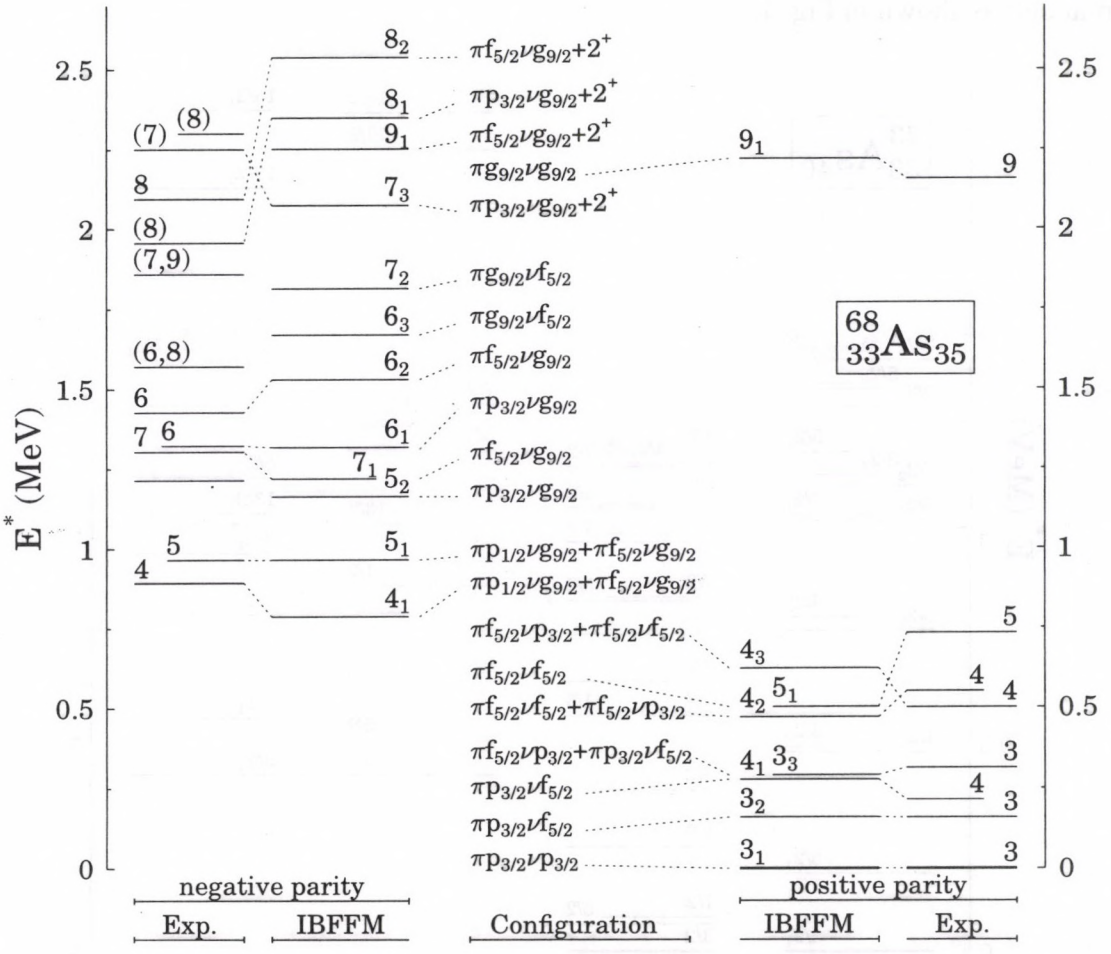

Fig. 1. Comparison of the experimental and theoretical IBFFM energy spectra of the low-lying states in ^{68}As

[1] D. Sohler *et al.*, in *Proc. 9th Int. Symp. on Capture Gamma-Ray Spectroscopy*, ed. by G. Molnár and T. Belgya (Springer, Budapest, 1996) in print.

Structure of ^{73}As

D. Sohler, Zs. Podolyák,[1] J. Gulyás, T. Fényes, A. Algora,
Zs. Dombrádi, S. Brant[2] and V. Paar[2]

[1] Laboratori Nazionali di Legnaro, Padova, Italy
[2] Department of Physics, Faculty of Science, University of Zagreb, Zagreb, Croatia

Based on in-beam γ- and electron-spectroscopic measurements, we have proposed a new level scheme for ^{73}As up to 1.4 MeV excitation energy, and deduced spins and parities of the levels [1].

Electromagnetic moments and transitions probabilities were calculated in the framework of interacting boson–fermion model (IBFM) and reasonable agreement was obtained between the experimental and theoretical results. The calculated energy spectrum compared with the experimental data is shown in Fig. 1.

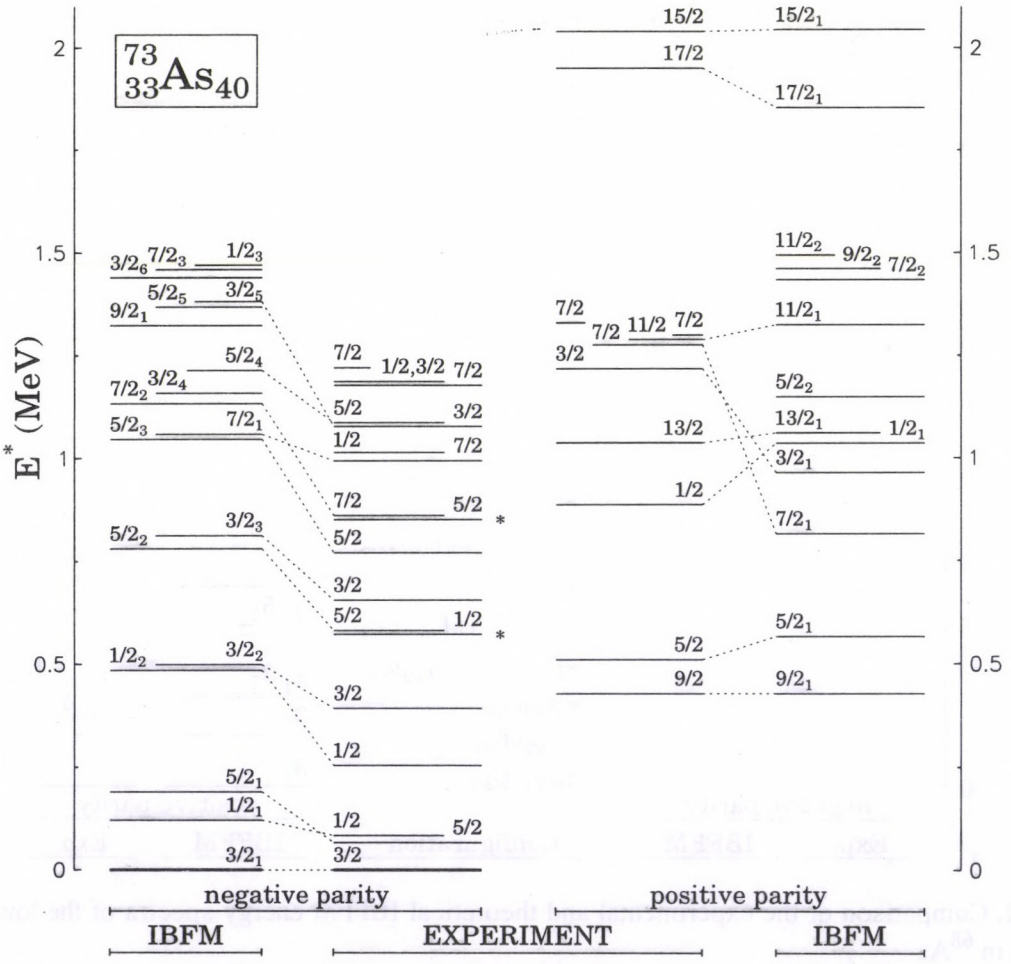

Fig. 1. The calculated IBFM energy spectra of the low-lying states of ^{73}As in comparison with experimental data. The levels marked with stars (*) might be intruder states.

[1] D. Sohler *et al.*, in *Proc. 9th Int. Symp. on Capture Gamma-Ray Spectroscopy*, ed. by G. Molnár and T. Belgya (Springer, Budapest, 1996) in print.

Level scheme of ^{109}Sn

I. Dankó, Z. Gácsi, Zs. Dombrádi, J. Gulyás and A. Krasznahorkay

As a continuation of our γ-ray and conversion electron spectroscopic study of the ^{106}Cd(α, nγ)^{109}Sn reaction [1], we have extended the level scheme of ^{109}Sn on the basis of the coincidence measurements. The low-energy part of the proposed level scheme is shown in Fig.1. For the overlapping region, our results are in agreement with those of the most recent (α, n) and heavy-ion studies [2]. On the other hand, several new coincidence relations were found giving support to the existence of the first excited state at about 14 keV above the ground state. Some of the strongest γ-rays observed previously in the decay study were also measured by us without any coincidence relations. Their placement in the level scheme is ambiguous, as they can decay either to the ground state or to the 14 keV state.

The spin and parity values were assigned to the excited states on the basis of the multipolarities of the transitions and the excitation functions of the states. The available γ-ray angular distribution results and log ft values [2] were also taken into account. The 0 keV $5/2^+$, 14 keV $7/2^+$, 926 keV $3/2^+$ and the 1270 keV $11/2^-$ states are expected to have $\nu d_{5/2}$, $\nu g_{7/2}$, $\nu d_{3/2}$ and $\nu h_{11/2}$ dominant one-quasiparticle configuration, respectively, according to the systematics of odd Sn nuclei. The $\nu s_{1/2}$ quasiparticle state was not excited in the present experiment. The other states can be considered as one- and two-phonon coupled states or three- and five-quasiparticle states.

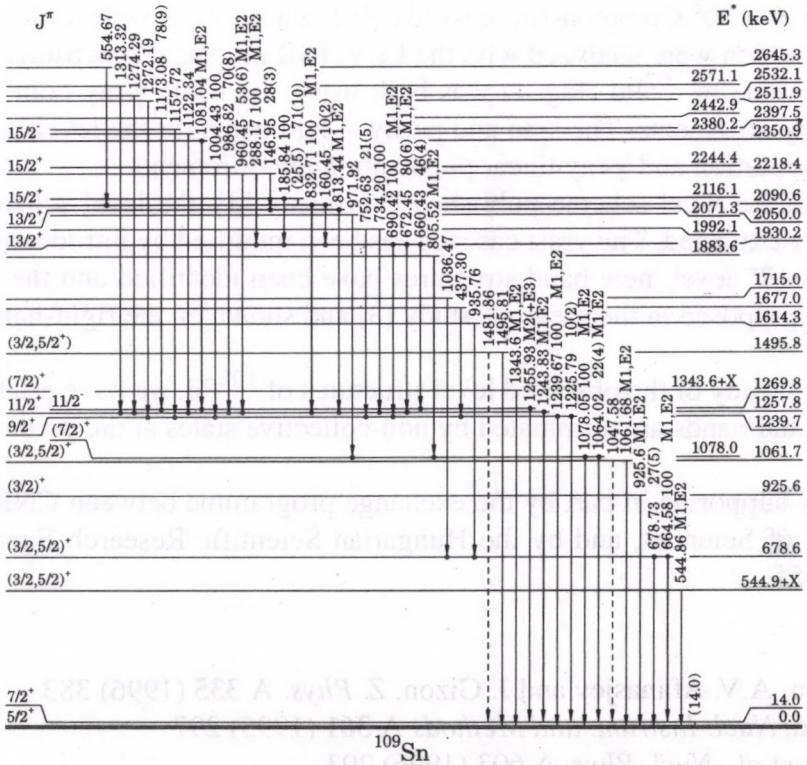

Fig. 1. Low-lying level scheme of ^{109}Sn from (α, n) reaction. (X denotes 0 or 14 keV.)

[1] I. Dankó *et al.*, ATOMKI *Annual Report 1995*, p.13

[2] L. Käubler *et al.*, *Z. Phys.* **A351** (1995) 123, and references therein

Evidence for multiple band terminations in ^{102}Pd

J. Gizon,[1] A. Gizon,[1] B.M. Nyakó, J. Timár, L. Zolnai, A.J. Boston,[2] Gh. Căta-Danil,[1] J. Genevey,[1] D.T. Joss,[2] N.J. O'Brien,[3] C.M. Parry,[3] E.S. Paul,[2] D. Santos,[1] A.T. Semple,[2] A.V. Afanasjev[4] and I. Ragnarsson[4]

[1] ISN, IN2P3-CNRS/Université Joseph Fourier, F-38026 Grenoble Cedex, France
[2] Oliver Lodge Laboratory, University of Liverpool, Liverpool L69 3BX, UK
[3] Department of Physics, University of York, Heslington, York, Y01 5DD, UK
[4] Department of Mathematical Physics, University of Lund, P.O. Box 118, S-22100 Lund, Sweden

It is well known that collective rotational bands can be terminated by non-collective single-particle states. Recent calculations [1] have suggested that such terminating states are accessible in the Ru–Pd nuclei with mass $A \approx 100$. These nuclei are known to be collective at low spin and are predicted to have configurations which are yrast up to their terminations in the $I = 30 - 35$ $\hbar$ spin range.

Based on these predictions an experiment has been performed to search for such terminating configurations in the nucleus ^{102}Pd and follow them up to their maximal spins. The nucleus ^{102}Pd was populated in the ^{70}Zn + ^{36}S reaction at 130 MeV bombarding energy using the Vivitron accelerator at CRN, Strasbourg. The emitted γ-rays were detected by means of the EUROGAM II spectrometer.

Approximately 6×10^8 Compton-suppressed coincidence events were sorted off line into $E_{\gamma_1} - E_{\gamma_2} - E_{\gamma_3}$ cubes which were analyzed with the LEVIT8R graphical spectrum analysis package [2]. The level scheme of ^{102}Pd (Fig. 1) was built using the triple γ-ray coincidence relationships and intensity arguments. The spin and parity assignments for the levels are mainly based on directional correlation and γ-ray linear polarisation measurements.

With respect to the level scheme published previously [3], the level scheme of ^{102}Pd has been considerably extended. The yrast cascade has been modified by introducing three E2 transitions above the 12^+ level, new band structures have been identified and the existence of the band, tentatively proposed in the previous study [3] and shown on the right-hand side of Fig. 1, is confirmed.

From a detailed study of the observed level structures of ^{102}Pd, we have established that several of the rotational bands are terminated by non-collective states at the predicted spin values.

This work was supported in part by the exchange programme between CNRS and the Hungarian Academy of Sciences, and by the Hungarian Scientific Research Fund, OTKA under contract No. 20655.

[1] I. Ragnarsson, A.V. Afanasjev and J. Gizon, *Z. Phys.* A **335** (1996) 383
[2] D.C. Radford, *Nucl. Instrum. and Methods* A **361** (1995) 297
[3] D. Jerrestam *et al.*, *Nucl. Phys.* A 603 (1996) 203

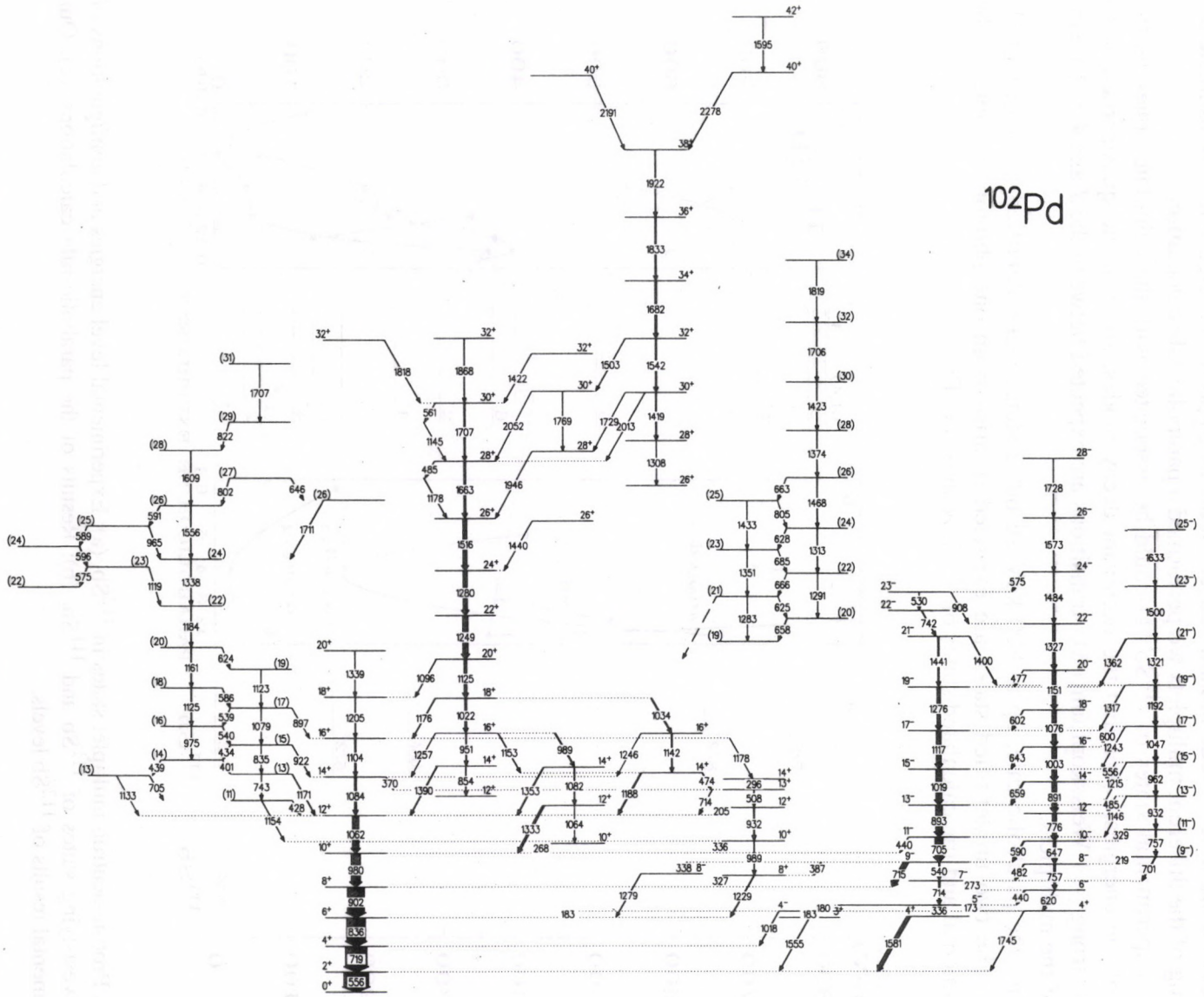

Fig. 1. The proposed level scheme of ^{102}Pd

Parabolic rule description of ^{112}Sb

Zs. Dombrádi, M. Fayez Hassan, J. Gulyás, I. Dankó and Z. Gácsi

The lowest lying states of ^{112}Sb, according to Fig. 1(a), are expected to be members of the proton–neutron multiplets predominantly based on the $\pi d_{5/2}$ proton configuration. To estimate the splitting of the different multiplets we performed a parabolic rule calculation.

Our experimental states of ^{112}Sb [1] could be associated with the calculated ones on the basis of the energies, spins and the dominant decay modes, since in the quasiparticle shell model strong ($\approx$ 1 Weisskopf unit) M1 transitions are expected between the J and $J \pm 1$ members of the multiplets.

Using the parabolic rule, up to 800 keV all but 2 states were identified as quasi-particle states. The two unidentified states are expected to arise from one phonon multiplets. The experimental and the calculated states of ^{112}Sb is shown in Fig. 1.

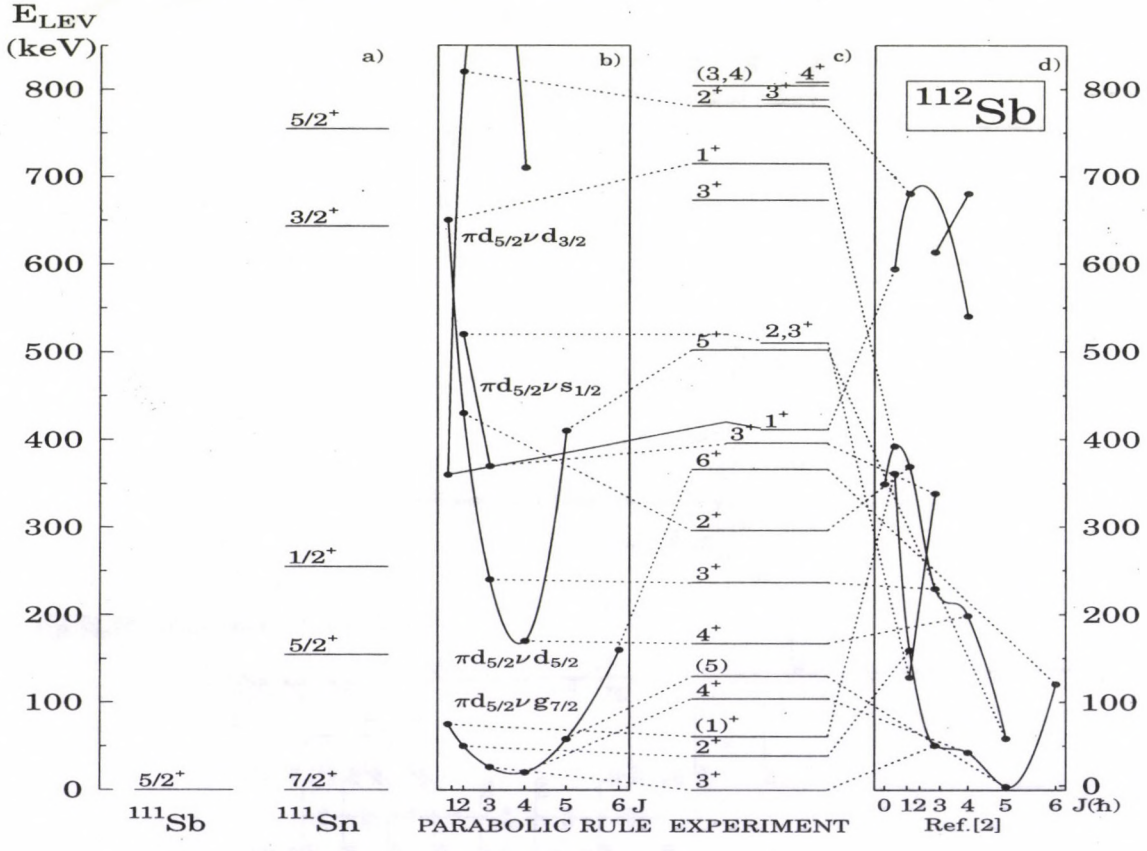

Fig. 1. Proton–neutron multiplet states in ^{112}Sb. (a): Experimental level energies and configurations of the lowest-lying states of ^{111}Sb and ^{111}Sn. (b): Results of the parabolic-rule calculations. (c): Our experimental results of ^{112}Sb levels.

[1] M. Fayez Hassan *et al.*, in *Capture Gamma-Ray Spectroscopy* (1996) in print.
[2] Gunsteren *et al.*, *Nucl. Phys.* **A266**, 365 (1976).

Negative-parity levels of ^{124}I

I. Dankó, Zs. Dombrádi, J. Gulyás and M. Fayez Hassan

γ-ray, γγ-coincidence and internal conversion electron spectra from the ^{124}Te(p, $n\gamma$)^{124}I reaction were measured at different bombarding proton energies earlier [1]. These experimental data have enabled a significant extension of the level scheme of ^{124}I and assignment of the spin-parity values on the basis of the transition multipolarities, the Hauser–Feshbach analysis of the (p, n) reaction cross sections, the decay properties of levels and the available γ-ray angular distribution data [2].

According to the γγ-coincidence data, the level scheme of ^{124}I have been splitted into two separate groups of levels having different parities, similarly to the neighbouring odd–odd ^{128,130}I and ^{122,124}Sb nuclei. The low-lying negative-parity part of the deduced level scheme of ^{124}I is shown in Fig.1. It is expected that the lowest lying negative-parity states of ^{124}I belong to the $\pi d_{5/2}\ \nu h_{11/2}$ and $\pi g_{7/2}\ \nu h_{11/2}$ two-quasiparticle multiplets. Detailed interacting boson–fermion–fermion model (IBFFM) calculation is in progress.

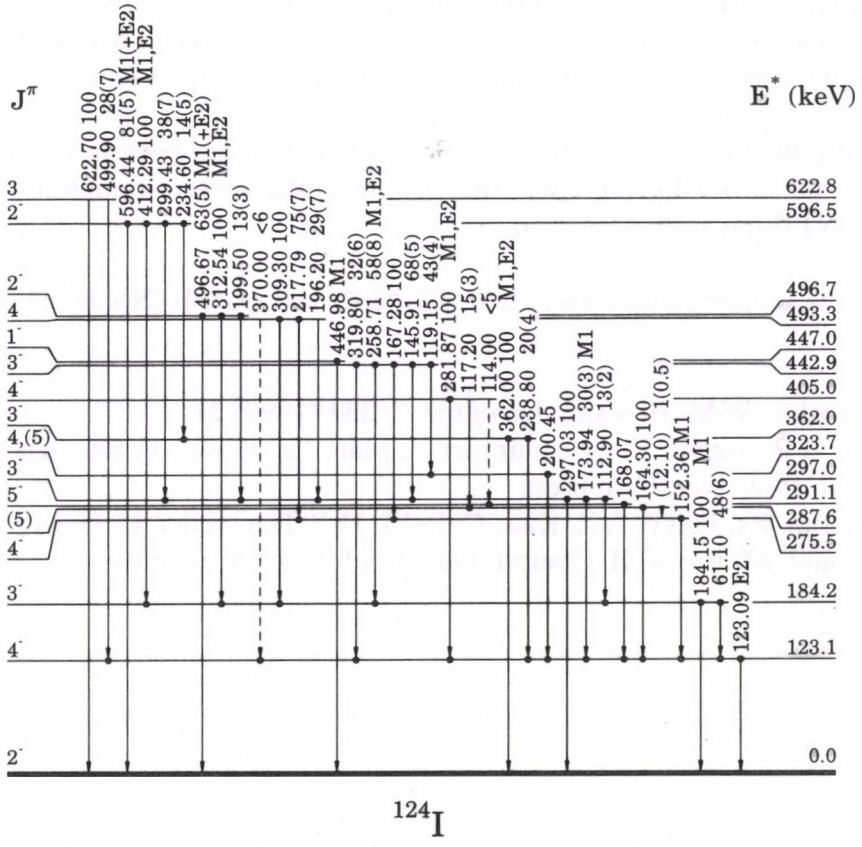

Fig. 1. Low-lying negative-parity states of ^{124}I

[1] I. Dankó *et al.*, ATOMKI *Ann. Rep. 1994*, p.14
[2] J. Burde *et al.*, *Nucl. Phys.* **A385**(1982)29

The ^{144}Sm–α optical potential at astrophysically relevant energies derived from ^{144}Sm(α,α)^{144}Sm elastic scattering

P. Mohr,[1] T. Rauscher,[2] H. Oberhummer,[1]
Z. Máté, Zs. Fülöp, E. Somorjai, M. Jaeger,[3] G. Staudt[4]

[1] Technische Universität, Vienna, Austria
[2] Universität Basel, Switzerland
[3] Universität Stuttgart, Germany
[4] Universität Tübingen, Germany

The calculated reaction rate for the p–process production of ^{144}Sm by the photodisintegration reaction ^{148}Gd(γ,α)^{144}Sm is uncertain by a factor of 10 [1]. This rate was derived from the ^{144}Sm(α,γ)^{148}Gd inverse reaction cross-section calculated with different potentials.

For the determination of the ^{144}Sm–α optical potential we measured the angular distribution of ^{144}Sm(α,α)^{144}Sm scattering at the energy $E_{\rm lab}$ = 20 MeV with high accuracy [2]. Using the known systematics of α–nucleus optical potentials we are able to derive the ^{144}Sm–α optical potential at the astrophysically relevant energy $E_{\rm c.m.}$ = 9.5 MeV with very limited uncertainties.

Using our potential the ^{144}Sm(α,γ)^{148}Gd cross section has been reduced by a factor of 1.5 compared to the so far lowest value, thus, the theoretical overestimation of the experimental cross sections [3] has been decreased.

This work was supported by OTKA (No. T016638) and OMFB (No. B123, No. B43).

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Experimental cross section of $^{144}Sm(\alpha,\gamma)^{148}Gd$

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The ^{144}Sm is among the most interesting *p*-nuclei from different points of view [1]. On one hand, isotopic anomalies have been observed for different *p*-isotopes of elements, among them for Sm. On the other hand, ^{144}Sm–^{146}Sm is considered as a candidate for a suitable *p*-process chronometer. Up to now, the key reaction of the nucleosynthesis of the ^{144}Sm—the $^{144}Sm(\alpha, \gamma)^{148}Gd$—has not been studied experimentally.

The cross section of the $^{144}Sm(\alpha, \gamma)^{148}Gd$ reaction have been measured in the bombarding energy range of 10.5–13.4 MeV, using activation method based on the off-line α-activity measurement of the ^{148}Gd residual nucleus. The long measuring time of the alpha decay demanded the utilization of solid state nuclear track detectors (SSNTD). Test measurement has also been performed by surface barrier Si detector in an underground laboratory (Gran Sasso) having very low background. The first results, compared to the latest statistical model calculations have been presented at the *Fourth Int. Conf. on Nuclei in the Cosmos*, Notre Dame, Indiana, USA, June 20–27, 1996 [2].

This work was supported by OTKA (No. T016638) and OMFB (No. B123, No. B43).

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Prediction of ^{144}Sm$(\alpha,\gamma)^{148}$Gd reaction rates in the statistical model

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The largest uncertainties in the calculation of cross sections and reaction rates for the reaction ^{144}Sm$(\alpha,\gamma)^{148}$Gd stem from the optical potential employed for determining the transmission coefficients in the α-channel.

We presented a new calculation of the reaction rates for the capture reaction ^{144}Sm$(\alpha,\gamma)^{148}$Gd, utilizing an $\alpha+^{144}$Sm potential derived from most recent α-scattering data [1]. The new rate seems to be in reasonable agreement with preliminary data from the currently performed ^{144}Sm$(\alpha,\gamma)^{148}$Gd experiment [2]. This experiment showed a discrepancy of a factor of 3–4 between experimental cross sections and those calculated in the (global) statistical model with a global α-potential. This underlines that after showing that neutron and proton global optical potentials and improved level densities give fully satisfactory results, the remaining task for astrophysical applications is the determination of an accurate global α-potential.

This work was supported by OTKA (No. T016638.) and OMFB (No. B123., No. B43.).

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First Identification of $\nu f^3_{7/2}$ Excitations in ^{151}Dy

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β decay studies in the $Z > 64$ and $N > 82$ region can lead to valuable spectroscopic information considering that only the fast $\pi h_{11/2} \rightarrow \nu h_{9/2}$ Gamow–Teller decay process is allowed. In contrast with in-beam studies following fusion–evaporation reactions in which only yrast or close yrast states are populated, β decay processes have a different structural selectivity which provides information on shell model configurations in both parent and daughter nuclei.

We have studied the β decay process of ^{151}Ho in to ^{151}Dy. The experiment was carried out at the GSI On-line mass separator facility using 5 MeV/A ^{58}Ni UNILAC beams on a ^{97}Mo enriched target, which was placed in front of a thermal ion source. Following ion extraction and mass-separation a secondary beam of $A = 151$ was deposited on a tape and transported to the measuring points. Two different arrangements were used in this experiment. In the first site two Ge(Li) detectors (with 40% and 70% efficiency) and a Ge telescope (small planar shaped +20% efficient Ge detector) were used for single, γγ and γX coincidence measurements. At the second position absolute e^- conversion coefficients measurements were performed using a mini-orange-type electron spectrometer and a Ge(Li) detector.

The new level scheme was deduced on the basis of the γγ, γX coincidence data and the obtained conversion coefficients. The level scheme contains many new levels and transitions compared to the former work of Batist *et al.* [1].

Shell model calculations for ^{151}Dy using experimental interactions [2] predict a $7/2^-$ ground state and $5/2^-$, $3/2^-$ states as the first and second excited states with a dominant $f^3_{7/2}$ component. Even though this behaviour was formerly observed in the $N = 87$ isotones, there were no candidates for the $5/2^-$ and $3/2^-$ states in ^{151}Dy from former in-beam and decay studies [3]. In the present work these members of the $f^3_{7/2}$ multiplet have been identified for the first time (states at 209 keV and 366 keV excitation energy) [4].

This work was supported by CICYT (Spain) under contract AEN94-0833-C02-01. One of us (A. Algora) gratefully acknowledges the support of the "World Bank Competition for Young Scientists" OTKA contract W015617.

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Spectroscopy of high spin oblate states in ^{152}Dy

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The nucleus ^{152}Dy exhibits a triple shape co-existence (oblate single particle states, normal deformed and superdeformed collective bands) at high spins [1]. An experiment aiming at the further studies of these shapes was performed using the EUROGAM II detector array [2] (CRN, Strasbourg). The reaction ^{124}Sn(^{34}S, 6n)^{152}Dy was applied at a beam energy of 182 MeV. As part of the complete spectroscopic study of this nucleus the new experimental data have been analyzed with the aim to determine the spin-parity values of the high spin oblate states. The 24 four-element clover detectors of the detector array were used as Compton polarimeters to determine the linear polarization of the gamma transitions [3]. Illustrative data from the results of the present work are shown in Fig. 1. The transition multipolarities were determined using a combination of the polarisation data and the results from directional correlations (DCO) analysis. A similar analysis for the collective structures is in progress.

This work is supported by OTKA (T20655) and by MKM – British Council exchange programme.

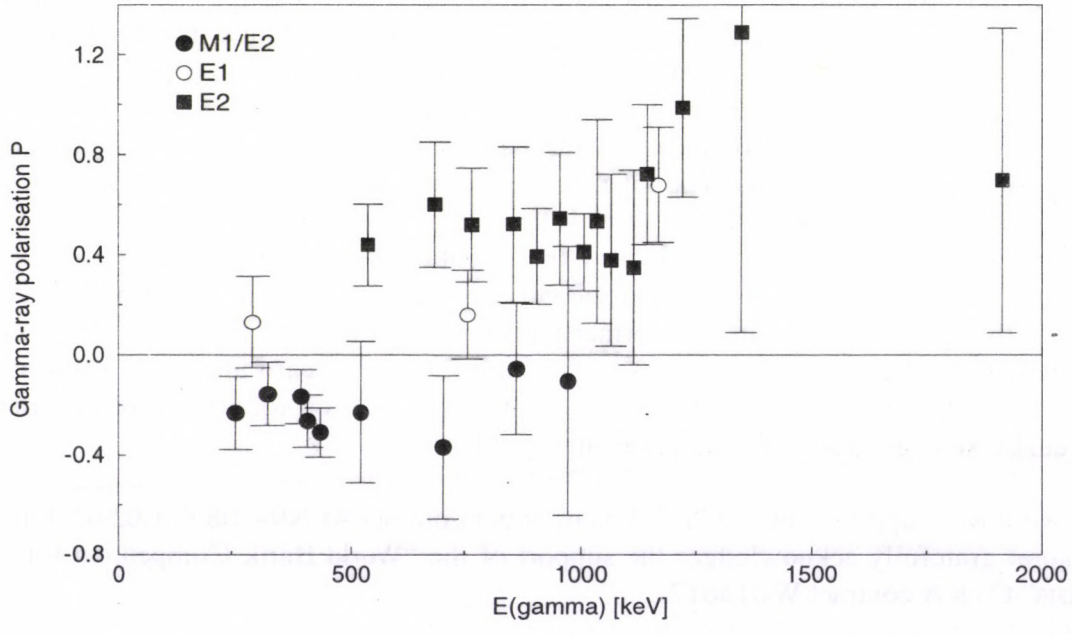

Fig. 1. The measured polarisation P of the γ-transitions deexciting the high spin oblate states in ^{152}Dy.

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Dipole cascades in ^{190}Hg

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Several level structures characterized by dipole cascades and cross-over quadrupole transitions, have been observed recently in some Hg nuclei with mass number larger than 190 [1]. These structures look in many respects similar to the 'shears bands' observed in the Pb nuclei [2]. However, a recent lifetime analysis of such a cascade in ^{192}Hg showed that its structure cannot be explained by the 'shears effect' [1]. The observation of similar structures in the lighter Hg isotopes can help to identify the configuration of such type of 'dipole bands' in Hg nuclei.

In a recent EUROGAM II. experiment high spin states of ^{190}Hg have been populated with the primary aim of studying the effect of octupole vibrations on the superdeformed bands of this nucleus. Results have been published in refs. [3, 4]. The large amount of data (~ 5×10^8 events) also enabled us to extend considerably the normal deformed part of the level scheme of ref. [5], and to observe 'dipole bands' in ^{190}Hg.

Two types of 'dipole bands' have been observed, one with cross-over E2 transitions and the other without cross-over transitions. These cascades are connected to the negative parity bands (band 6, band 7 and band 9 in ref. [5]) and to the yrast band through an irregular level structure, respectively.

This work was supported in part by the exchange programme between the British Council and the Hungarian Academy of Sciences, and by the Hungarian Scientific Research Fund, OTKA under contract No. 20655.

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Excited hyperdeformed bands in ^{234}U

A. Krasznahorkay

In our recent work [1] we have observed several sharp resonances in the ^{235}U$(d, pf)^{236}$U reaction above the inner barrier of the second well but below the barriers of the third well and interpreted them as highly excited states in the third minimum of the potential barrier.

In this work we reanalyzed the results of Blons et al. [2] concerned to ^{234}U in a similar way as we did previously for ^{236}U. We supposed that each of the resonances shown in Fig. 1 consists of a complete rotational band. The energy of the band heads, the absolute intensity of the bands and an inertia parameter ($\hbar^2/2\Theta$) were fitted to the experimental data. The obtained inertia parameter agrees well with the predicted value for the HD states.

The angular distribution of the fission fragments was also calculated and compared to the experimental data. Good agreement has been obtained which also supports that all of the peaks shown in Fig. 1 contains a complete rotational band instead of a definite state with a well defined J^{π}.

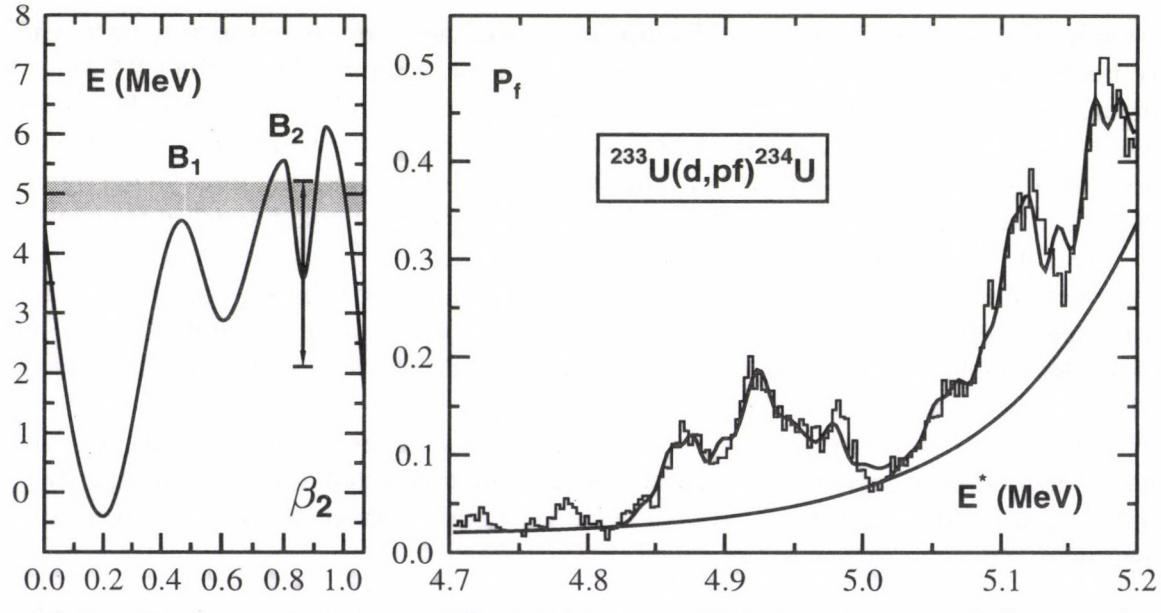

Fig. 1. a) Potential energy curve for ^{234}U as a function of the quadrupole deformation parameter β_2. The different values for the depth of the third well were taken from the literature [3, 4]. The shadowed excitation energy region was presently analyzed. b) Fission probability of ^{236}U as a function of the excitation energy. The full curve is a result of the fit with $\hbar^2/2\Theta = 2$ keV.

In conclusion the experimental results of Blons et al. [2] obtained for ^{234}U also support the presence of a deep third well which was not considered before but which is predicted by the latest theoretical calculations [3].

This work has been partly supported by the OTKA foundation, No: 7486.

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Hyperdeformed states in ^{236}U

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The fission probability of ^{236}U has been studied as a function of the excitation energy by measuring the protons from the ^{235}U(d, p) reaction in coincidence with fission fragments in order to get information about the hyperdeformed (HD) states lying in the third well of the potential barrier (see Fig. 1a).

The experiment has been carried out at the Debrecen 103 cm isochronous cyclotron and at the Munich Tandem accelerator. The energy of the outgoing protons was analyzed by a split pole and a Q3D magnetic spectrographs. The fission fragments have been detected by two position sensitive avalanche detectors. Typical proton spectra in coincidence with the fission fragments are shown in Fig. 1b) as a function of the excitation energy.

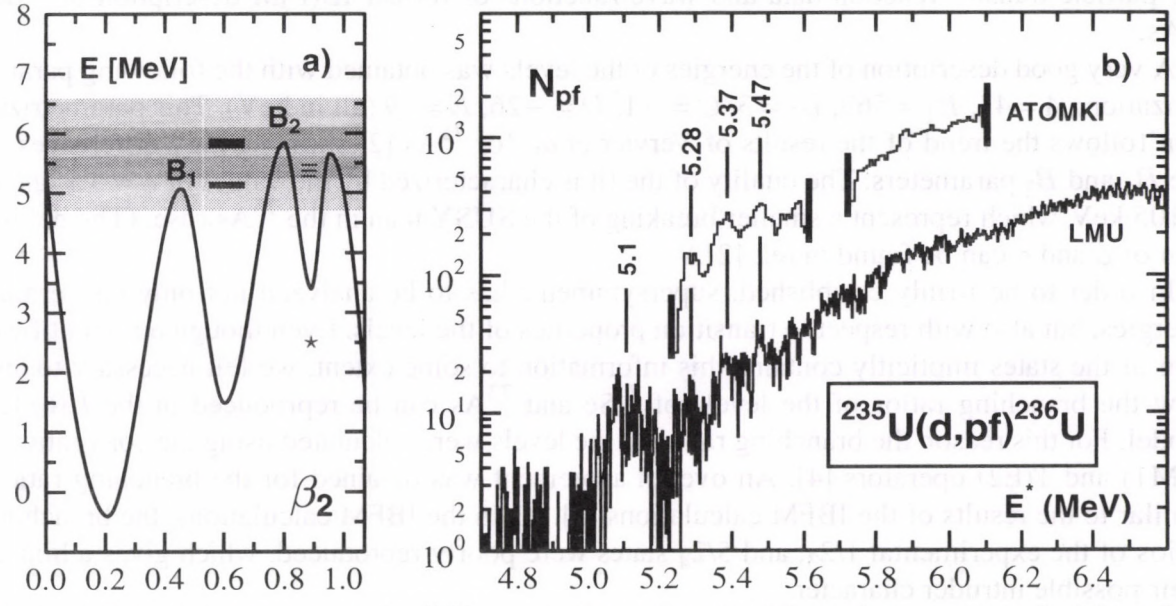

Fig. 1. a) Potential energy curve for ^{234}U versus the quadrupole deformation parameter β_2. The values for the depth of the third well are from refs. [1, 2]. b) Proton spectra corresponding to the shaded energy region in a) measured in ATOMKI and in Munich (LMU).

A highly damped superdeformed (SD) vibrational resonance which is very close to the top first barrier B_I is clearly seen at 5.1 MeV. Above this resonance we observed some sharper peaks (FWHM ≈ 30 keV) similarly to our previous results [3]. These resonances do not appear to be appreciably damped although they are above the top of the inner barrier, so these sharp resonances cannot be associated to SD states lying in the second well. These results support the presence of a deep HD minimum as predicted recently by Ćwiok et al. [1].

This work has been partly supported by the OTKA foundation No: 7486, the DAAD, the NWO and the DFG under IIC4-Gr 894/2.

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Application of the $U(6/12)$ Supersymmetry to ^{73}As

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Our former work on ^{74}As [1] demonstrates that the $U_\pi(6/12)\otimes U_\nu(6/12)$ supersymmetry (SUSY) scheme gives an approximate description of the states of the ^{74}Se, ^{75}Se, ^{73}As and ^{74}As supermultiplet. A closer look at the obtained results, as well as separate calculations for ^{74}Se, ^{75}Se and ^{74}Se, ^{73}As using $U(6/12)$ show that this supersymmetry works better for the ^{74}Se, ^{73}As (sub)supermultiplet than for the ^{74}Se, ^{75}Se one.

In order to further test the applicability of $U(6/12)$ to ^{74}Se, ^{73}As we have recalculated the energies of the states of this supermultiplet using the hamiltonian given by Vervier *et al.* [2] and the new experimental data of [3]. As in the former study [1], we have relied on a careful identification of the states for the calculations based on the decay properties of the levels, single particle transfer reaction data and wave functions of former IB(F)M description of ^{74}Se, ^{73}As.

A very good description of the energies of the levels was obtained with the following parametrization: $A = 43$, $B_1 = 569$, $B_2 = 3$, $C = -1$, $D = -26$, $E = 39$ (all in keV). This parametrization follows the trend of the results of Vervier *et al.* for ^{75}As [2] showing only differences in the B_1 and B_2 parameters. The quality of the fit is characterized by the values of $\phi = 3\%$ and $\sigma = 105$ keV, which represent a smaller breaking of the SUSY than in the ^{75}As case. (The definition of ϕ and σ can be found in ref. [2].)

In order to be firmly established, supersymmetry has to be analyzed not only concerning energies, but also with respect to transition properties of the levels. Even though our identification of the states implicitly contains this information to some extent, we felt necessary to test how the branching ratios of the levels of ^{74}Se and ^{73}As can be reproduced in the $U(6/12)$ model. For this reason the branching ratios of the levels were calculated using the conventional T(M1) and T(E2) operators [4]. An overall agreement was obtained for the branching ratios, similar to the results of the IBFM calculations [3]. As in the IBFM calculations, the branching ratios of the experimental $1/2_3$, and $5/2_4$ states were poorly reproduced, which gives a hint of their possible intruder character.

This work was supported by the Hungarian Scientific Research Foundation (OTKA, grant No. T14321) and by the Swiss National Science Foundation.

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Symmetric interactions in cluster systems

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Recently it was shown that Hamiltonians obeying multichannel dynamic symmetry can be constructed for cluster systems [1]. This means that different cluster configurations of the same nucleus can be described by the same Hamiltonian. It contains both intercluster forces and coupling interactions between the relative motion and internal cluster degrees of freedom. These Hamiltonians can be determined from eigenvalue equations [1] within the framework of the Semimicroscopic Algebraic Cluster Model [2]. An important point is that this kind of phenomenological interaction is able to describe the spectra of different clusterizations of the same nucleus reasonably well.

Based on the previous results here we address the following questions concerning further generalizations. *i)* Can the shell model and the cluster model share a symmetric Hamiltonian? *ii)* Is it possible to derive a systematic mass-number-dependence of the Hamiltonian for simple cluster configurations, based on the multichannel dynamic symmetry?

The harmonic oscillator Hamiltonian constitutes a straightforward answer to question *i)* [3]. However, it is too simple to give realistic results. The main result of our present investigation is that the shell and cluster models are able to incorporate identical Hamiltonians corresponding to $U(3)$ in a natural way, thus they define the common intersection of the two models. As a consequence, the energy spectrum of the two models coincide, and pure cluster model states have pure shell model configurations as well.

Concerning question *ii)*, we can derive a systematic interaction for cluster configurations containing alpha-like clusters if we make a further assumption; namely that the interaction between two clusters is the same in different configurations.

This work is supported by the JSPS and OTKA (T14321) projects.

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Multiconfigurational cluster structure of nuclei: aspects of electromagnetic transitions

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Models based on molecular (cluster) configurations of nuclei play an important role in explaining nuclear excitations in a wide energy domain ranging from the ground-state region to that of the quasi-molecular resonances. These diverse phenomena were successfully described by the semimicroscopic algebraic cluster model (SACM) developed in the past few years [1].

Recently a new feature of the SACM has been identified when it was shown that it can be used to describe different clusterizations of the same nucleus simultaneously in terms of the so-called multichannel dynamic symmetry [2]. This procedure is based on the $SU(3)$ basis used in the description of all the clusters, their relative motion as well as the united nucleus. The first tests of this new symmetry concept concerned exclusively the energy spectrum of nuclei assuming different cluster configurations.

However, if this symmetry exists then it must also show up in the electromagnetic transition schemes, therefore we launched a study of the electromagnetic transitions of the ^{24}Mg nucleus assuming ^{12}C + ^{12}C and ^{20}Ne + α configurations. This study also aimed at a more complete description of this nucleus, which has already been investigated in terms of a "single-channel" ^{12}C + ^{12}C configuration [3]. Now we also considered $E1$ and $E3$ transitions in the ground-state region, as well as $E2$ transitions from the highly excited states (appearing as ^{12}C + ^{12}C resonances) to the ground-state region [4], interpreted as $2\,\hbar\omega \rightarrow 0\,\hbar\omega$ transitions.

We found that using the dynamic symmetry approximation of the SACM [1] $E1$ and $E3$ transitions are allowed only in the ^{20}Ne + α picture, which is an indirect consequence of the identical nature of the clusters in the ^{12}C + ^{12}C channel. This finding is in line with the fact that most of these transitions are known to be weak. In order to estimate the absolute value of the $2\hbar\omega \rightarrow 0\hbar\omega$ $E2$ transitions we used a sum rule formula and we found that the prediction based on the two channels coincided: almost all the possible $2^+(2\hbar\omega) \rightarrow 0^+(g.s.)$ transitions were forbidden in both cases, and the few allowed ones had comparable strength of $\simeq 3-5$ W.u.

This work was supported by the JSPS and OTKA (grant No. T14321).

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Isospin effects in the Semimicroscopic Algebraic Cluster Model

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With the increasing number of applications the need for systematic parametrization of the Hamiltonian (and other operators) of the Semimicroscopic Algebraic Cluster Model [1] appeared naturally. The first attempt in this direction was establishing a standardized form of the SACM Hamiltonian for core+α-particle-like cluster systems, which was then used to determine the dependence of the phenomenologic parameters on the mass number in the A = 16 to 20 mass region [2].

Until now no isospin-dependent terms were considered in the operators, although the quantum numbers T and T_z appeared explicitly in the labelling scheme of the basis throughout Wigner's $U^{ST}(4)$ spin–isospin group. As a consequence, the SACM treatment was restricted to states with the same T, and the interrelation of states of different nuclei belonging to isospin multiplets was not possible either. These circumstances lead us to considering isospin-dependence in the SACM.

As a first example we considered the chain of nuclei with A = 19 and described ^{19}F, ^{19}Ne and ^{19}O as core+α systems. ^{19}F and ^{19}Ne are mirror nuclei and there only a slight T_z-dependence of the Hamiltonian parameters appears. ^{19}O has states with T = 3/2, which also have isobar analogue states in the spectra of ^{19}F and ^{19}Ne. To include all these states in the simultaneous description of the three A = 19 nuclei we added T-dependent terms (like $C_2(U^T(2)) = T(T+1)$) in the Hamiltonian.

We also considered the isospin-dependence of electromagnetic transition probabilities. Here the change of charge number Z naturally requires T_z-dependence of the parameters. We considered 18 core+α-like systems and assuming a linear functional form on T_z, we determined a parameter systematics for the two parameters appearing in the $E2$ transition operator of the SACM [3]. Work is in progress to formulate β-decay processes in our model.

Having a systematic approach applicable to even and odd nuclei alike, we also plan to investigate whether the algebraic description can be extended to more complex symmetry schemes, such as supersymmetry. The existence of a supersymmetry scheme should manifest itself in correlated behaviour of the observables, which can be compared to the experimental data.

This work was supported by the OTKA grant No. T14321 and the Hungarian Academy of Sciences–CNRS collaboration.

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Semimicroscopic algebraic description of the ^{28}Si + ^{28}Si and ^{24}Mg + ^{24}Mg systems

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Previous applications of the Semimicroscopic Algebraic Cluster Model (SACM) [1] to nuclear molecular systems such as ^{12}C + ^{12}C [2] and ^{12}C + ^{16}O [3] showed that this model is able to describe the molecular resonances together with the ground-state region of the compound (i.e. the ^{24}Mg and ^{28}Si) nuclei. Based on the first results an extension of the method to heavier nuclear molecular systems, like ^{24}Mg + ^{24}Mg and ^{28}Si + ^{28}Si also seems worthwhile. These particular problems deserve attention for other reasons as well: the corresponding compound systems are in the $N = Z$ region, away from the valley of stability, studied extensively by radioactive nuclear beams. The use of the $SU(3)$ shell model scheme for the description of these fp-shell nuclei may be questioned, due to the $N = Z = 28$ shell closure. Recent experimental results [4], however, did not support the idea of this shell closure. We considered the ^{28}Si + ^{28}Si and the ^{24}Mg + ^{24}Mg cluster systems in the $SU(3)$ dynamic symmetry limit of the SACM and fitted the experimental spectrum with the analytic expression of the energy formula

$$E = \epsilon + \gamma_R n_\pi + \delta_C C^{(2)}{}_{SU_C(3)} + \delta C^{(2)}{}_{SU(3)} + \theta K^2 + (\beta + \eta n_\pi) J(J+1)$$

valid in this limit. The low-lying part of the positive- and negative-parity spectrum was interpreted as $0\hbar\omega$ and $1\hbar\omega$ excitations of the relative motion, respectively. The molecular resonances were assigned to those excitations of the relative motion which were able to accommodate states with the highest known angular momenta, which turned out to be $6\hbar\omega$ and $8\hbar\omega$ for ^{56}Ni and ^{48}Cr, respectively. Calculating $B(E2)$ values for electric quadrupole transitions in the ground-state band of ^{48}Cr indicated that the validity of the $SU(3)$ dynamic symmetry approximation might be limited here. We also extracted the geometric content of the SACM by deriving an inter-cluster potential for the algebraic Hamiltonian. The potential functions showed relatively wide and flat shape (due to the identical nature of the two clusters), and a range close to the expected value.

This work is supported by the CONACyT-MTA collaboration (No. E120-550/95) and the OTKA (T014321 project).

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Clusterization of Heavy Nuclei and the $SU(3)$ Symmetry

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A possible extension of the Semimicroscopic Algebraic Cluster Model [1] to heavy nuclei was studied in Refs. [2, 3], in terms of the pseudo $SU(3)$ shell model scheme. We consider here an alternative way, based on the use of the real $SU(3)$ symmetry. This is not valid for heavy nuclei, but it does not necessarily mean that it is useless. What it really means is that we can not restrict ourselves to the leading representation of the orbital part of the wavefunction, and spin $S = 0$. For strong spin-orbit interactions shell model studies [4] indicate that the states fall into bands with extremely small interband quadrupole matrix elements. Moreover, the states obtained by diagonalising the Hamiltonian are remarkably close to the quasi-representations obtained by strong coupling of spin $S = 1$ with the $SU(3)$ irrep of the orbital part. These investigations seem to suggest that the leading term approximation can be considerably improved by taking into account also the $S = 1$ contribution, and still the problem remains tractable.

Based on this approximation we have investigated the effect of the structural selection rule for the Mo emission of the ground state of the ^{252}Cf in spontaneous fission processes. The mass-number dependence of the reciprocal frobiddenness [3] for the Mo decay turns out to have a single-bumped structure, fairly similar to that of the yield-curve found experimentally (Table 1).

Table 1. Comparison of the reciprocal forbiddenness in the different real $SU(3)$ approximations for the studied Mo–Ba fissions. The deformation parameters ε_2 are taken from Ref [5].

				Reciprocal forbiddenness	
A_{Mo}	A_{Ba}	ε_2^{Mo}	ε_2^{Ba}	S=0	(S=0)+(S=1)
102	150	0.30	0.22	0.0399	0.0366
103	149	0.32	0.22	0.0416	0.0384
104	148	0.32	0.22	0.0434	0.0400
105	147	0.33	0.20	0.0400	0.0369
106	146	0.32	0.18	0.0370	0.0343
107	145	0.32	0.17	0.0308	0.0288
108	144	0.30	0.15	0.0258	0.0243

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A mass formula for hypernuclei

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Ordinary matter consists of *u* and *d* quarks. Leaving aside even more exotic matter that contains *c*, *b* or *t* quarks, hypernuclei are defined as having at least one *s* quark. The most frequently occurring examples of hypernuclei have one Λ (= *uds*) in the $s_{1/2}$ shell. Some cases are known with one Σ (*uus*, *uds* or *dds*), two Λ's or one X (*uss* or *dss*), the latter two being of double strangeness [1].

The purpose of this investigation is to propose a mass formula for hypernuclei. It is based on the one hand on the standard nuclear mass formula due to Weizsäcker with the usual terms in it and, on the other hand, on the $SU(3)$ model of elementary particles. The mass formula is also inspired by recent efforts [2] to add a Wigner term to Weiszäcker's mass formula, which is given by the quadratic Casimir operator of the isospin–spin algebra $SU(4)$. If the strangeness degree of freedom is included in the problem [i.e., go from isospin $SU(2)$ to $SU(3)$], the Wigner term in the hypernuclear mass formula relates to $SU(6)$, in the spirit of the classification proposed by Gürsey and Radicati [3]. The ensuing problem can be considered at two levels: *i)* at the baryon level, taking a fundamental $SU(3)$ representation (1,0) which includes neutron, proton and Λ [this corresponds to Sakata's [4] $SU(3)$ model]; *ii)* at the quark level, using the standard $SU(3)$ model with colour.

We have at present worked out some aspects of the first approach: a complete classification is given for up to 6 baryons in the *s*-shell in the scheme

$$U_{FS}(6) \supset (SU_F(3) \supset U_Y(1) \otimes SU_T(2)) \otimes SU_S(2),$$

where *F* refers to flavour, *S* to spin, *Y* to hypercharge and *T* to isospin. For higher shells containing *n* neutrons and *z* protons, the favoured $SU_{FS}(6)$ and $SU_F(3)$ representations have been determined as a function of *n* and *z*. With these results a fit to known masses of Λ nuclei will be attempted.

This work was supported by the OTKA grant No. T14321 and the Hungarian Academy of Sciences–CNRS collaboration.

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On the α-decay of deformed actinide nuclei

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α-decay through a deformed potential barrier produces significant mixing of angular momenta when mapped from the nuclear interior to the outside. Using experimental branching ratios and either semi-classical or coupled-channels transmission matrices, we have found that there is a set of internal amplitudes which are essentially constant for all even–even actinide nuclei. These same amplitudes also give good results for the known anisotropic α-particle emission of the favored decays of odd nuclei in the same mass region.

We find that it is possible to describe all known branching ratios of even–even actinide nuclei with an internal α-particle wave function which is practically nucleus-independent. This model has a certain aesthetic appeal in itself and, with the as yet *ad hoc* assumption that there is no mixing between different daughter states under the barrier in the odd–even system, is capable of reproducing the known anisotropies in this mass region. This of course begs the question as to what physical model could generate such constant amplitudes. The best candidate would appear to be the notion that the α-particle amplitudes should be projected from the pair-correlated neutron and proton Nilsson-model states. In this mass region, the level density is high and the pair forces lead to a rather diffuse Fermi surface. One might then expect that the correlated ground-state wave function should vary rather slowly with the Fermi energy, or in other words with the nucleon numbers of the system.

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Effects due to the continuum on shell correction at finite temperatures

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Temperature dependent shell corrections are calculated taking the continuum spectrum of a finite depth mean field potential into account.

The Strutinsky method is extended in order to incorporate in a simple way both the continuum and the thermal effects [1].

The effect of the continuum is split up into a discrete term which includes Gamow resonances and an integral along a contour in the complex energy plane.

The resonances appear in the formalism in the same manner as bound states.
At low temperatures the resonances give the main part of the contribution due to the continuum. The method is applied to the particular case of neutrons in ^{208}Pb. The critical temperature for which the shell corrections are washed out completely is estimated to be at about $T = 2.5$ MeV.

This work was supported by the Swedish Royal Academy of Sciences, the NORFA, the CONICET, the J. S. Guggenheim Memorial Foundation and the Hungarian National Research Fund (OTKA) through Contract T17298.

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Two-particle – one-hole excitations in the continuum

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We studied the coupling of the single particle states to the two particle one hole (2p-1h) excitations within the framework of the multistep shell-model method (MSM).

The MSM solves the shell-model equations in terms of correlated bases.

The single particle basis used in this work includes single particle resonances in order to take the effect of the continuum into account approximately. The correlated p-h and p-p states are also formed from the s.p. basis which incorporates resonances therefore the approximation used here can be called as resonant multistep shell-model (RMSM) method.

The bases formed from the s.p. states, the particle states coupled to the correlated p-h states and the hole states coupled to the correlated p-p states are overcomplete due to the violation of the Pauli principle as well as the overcounting of states. This problem is solved in the MSM by introducing the overlap matrix [1].

In the RMSM the definition of the scalar product was generalized because of the resonant basis states [2].

The RMSM method was applied for the particular case when one neutron or proton is added to the ^{208}Pb double magic nucleus.

We calculated the spectrum of ^{209}Pb in order to analyze recent experimental data for neutron decay of high l states. Partial decay widths and branching ratios to the correlated 1p-1h states in ^{208}Pb were also calculated. The fragmentation of the s.p. strength was calculated for the $11/2^+$ and the $15/2^-$ states in ^{209}Bi. Good agreements with the available experimental data were achieved for states both in ^{209}Pb and ^{209}Bi nuclei [3].

This work was supported by the exchange program between the Hungarian Academy of Sciences and the Swedish Royal Academy of Engineering Sciences (IVA), the Swedish Institute and the Hungarian National Research Fund (OTKA) through Contract T17298.

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ATOMIC PHYSICS

Quasifree Electron Scattering on Atoms in the Inverse Kinematic System

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An essential feature of the energy spectrum of electrons associated with the ionization of the projectile in collisions between clothed atoms is the "Electron Loss Peak" (ELP). The peak is located near the projectile velocity and is interpreted as an elastic scattering between the projectile electron and the target atom. If the binding energy of the projectile electron is small compared to its kinetic energy, the process can be regarded as "quasi-free" electron scattering, and interesting phenomena, like the Ramsauer–Townsend (RT) effect [1] can be studied measuring the angular distribution of ELP [2]. The measurement of the RT effect is a sensitive tool to test ionic and atomic potentials. In case of ionic potentials, however, one is faced with the difficulty of producing dense ionic target. To avoid this problem, we suggest to use the inverse kinematics, i.e., to exchange the roles of projectile and target and transform the cross sections.

In the present work we measured absolute doubly differential cross sections for projectile ionization of He^0 (0.1 MeV/amu) in collision with Ne^0 for both the direct and inverse system in the whole angular range between 0° and 180° [3]. The data for $He^0 \rightarrow Ne^0$ and $Ne^0 \rightarrow He^0$ show a distinct RT minimum in the singly differential cross section around 100°. We found that the two data sets agreed within the error bars confirming the validity of the transformation procedure. However, changing to Ne^{3+} target, the loss peak was absent in the transformed spectrum at larger emission angles. This can be explained by the large cross section for the electron capture into bound states of the Ne ion: The electron of He^0 is captured by the ion rather than being scattered quasi-elastically.

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Absence of the cusp in the single-electron detachment spectrum of the He^- ion

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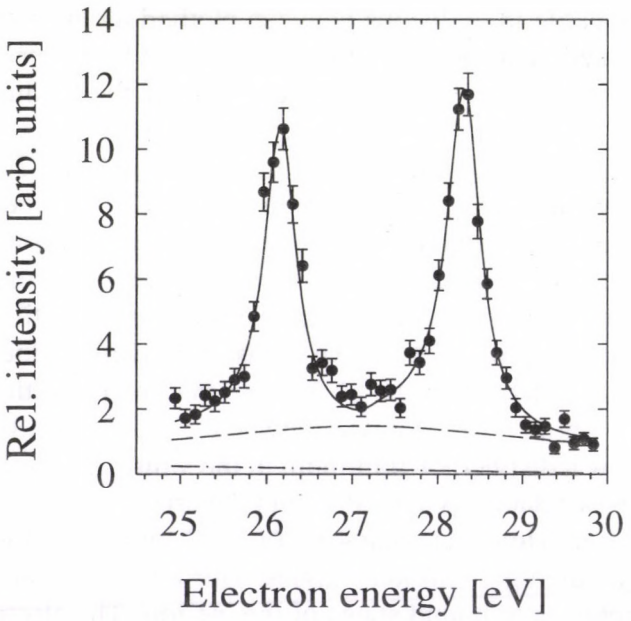
As a further step of our systematic investigation of the electron cusp (a singularity in the energy spectrum of the forward ejected electrons in atomic collisions) with *neutral* atomic projectile in the final state [1], in this work we studied the single-electron detachment (SED) from He^- [2]. The origin of the cusp is well understood for cases when the interaction between the outgoing projectile and the electron is characterized by long range (Coulomb or dipolar force). For SED from He^- the potential around the outgoing He^0 atom has short range, therefore no cusp is expected in this case. Furthermore, after the electron detachment the He atom remains in the 2^3S metastable state, which excludes the formation of a cusp-shaped peak via the excitation of a virtual resonance, a mechanism known to exist for the 2^1S state [3].

We measured the energy spectrum of the electrons emitted via SED in collisions of 200 keV He^- ions with He. SED was identified detecting the electrons in coincidence with the outgoing He^0 atoms. Taking the advantage of the method of the zero-degree electron spectroscopy carried out with good angular and energy resolution, the lines from the decay of the $(1s2p2p')$ $^4P^e$ shape resonance of He^- were completely resolved. The Figure shows the obtained spectrum. As is seen, no sign of the cusp peak can be observed between the two peaks. For the fitting of the spectrum we used the method proposed by Závodszky *et al.* [4]. For the resonance parameters we obtained the following values: E_r = 10.67±0.14 meV and Γ = 9.1±0.3 meV.



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Observation of low-lying resonance states of He^- at the 2^1S and 2^3S He thresholds

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In atomic physics, resonance states of very low energy (below 1 meV) electrons scattering on atoms are little known because of the experimental difficulties in carrying out measurements with such low-energy electrons. However, employing a translational electron spectroscopy method, which takes full advantage of the kinematic transformation of the velocities from the projectile to the laboratory frame, allows us to enhance this small energy scale, making it accessible to experiment.

According to Barrachina [1] such a low-energy virtual resonance state of the $He(2^1S) + e^-$ system is responsible for the cusp-like peak that was observed in 400 keV $He^0 \rightarrow Ar$ collision in the 0° electron spectrum measured in coincidence with the neutral He atoms [2]. The peak appears at the electron energy where the electron velocity matches that of the projectiles. A 400 keV He^0 beam produced by electron capture from He^+ ions contains about 76% 1^1S, 8% 2^1S and 16% 2^3S He atoms (effective beam). By producing pure 2^3S He beam and using the results of an earlier experiment, where 1^1S He beam was prepared [3], we were able to determine the cross section for all three long-lived states of He [4]. The broad peak that was observed in the case of 2^3S He beam (see fig. 1) can be attributed to the proximity of the 2S Feshbach resonance of He^-, whereas the sharp peak measured in the case of the effective beam is dominantly formed by the above mentioned low-lying virtual resonance of 2^1S He. From the shape of the spectra scattering lengths of 8 (+5, –3) a.u. and 120 (+80, –50) a.u. were obtained for the elastic electron scattering on the 2^3S and the 2^1S He atoms, respectively. The ratios of the cross sections integrated to the energy range indicated in fig. 1 are: $\sigma(2^1S)/\sigma(2^3S) = 9.8\pm6$, $\sigma(2^1S)/\sigma(1^1S) = 31\pm8$, $\sigma(2^3S)/\sigma(1^1S) = 3.2\pm0.8$.

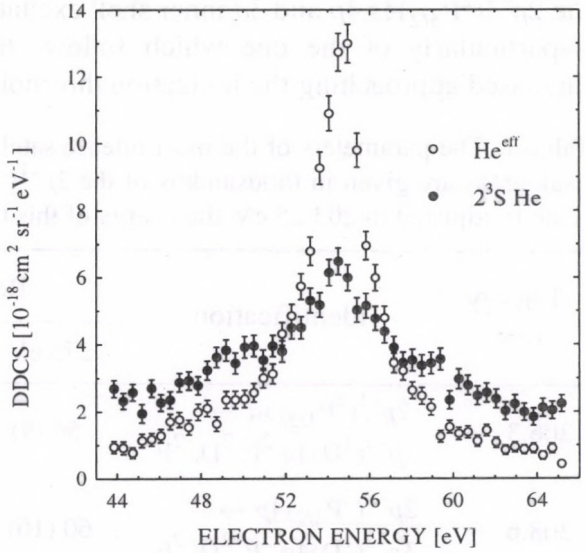

Fig. 1. Doubly differential cross sections measured at 0° at impact of a 400 keV 2^3S He and an effective beam on Ar target.

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Observation of Electron Impact Inner-Shell Excitation of Argon by means of Satellite Auger Spectra

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We have studied the inner-shell excited states of argon below the $2p$ thresholds for electron-impact excitation in the range of the incident energy E_0 = 275 – 1700 eV [1]. We carried this out through the measurement of the electrons emitted during the decay of the states. The corresponding satellite peaks in the spectra of the emitted electrons were separated from the normal (diagram) LMM Auger peaks by a special evaluating process based on the least-squares fit program EWA of Végh [2].

At all applied incident energies we could significantly improve the quality of the computer fit to the measured ejected electron spectra by means of adding certain satellite lines to the synthesized model spectra. These satellites correspond to the most probable transitions following the $2p^{-1}(^2P_{3/2})4s$,$4p$ and $3d$ inner shell excitations (Table 1). The intensity of the satellite peaks —particularly of the one which follows the dipole forbidden $2p^{-1}(^2P_{3/2})4p$ excitation— increased approaching the ionization threshold (E_0 = 275 – 300 eV).

Table 1. The parameters of the most intense satellites which are present in each measured spectra. The peak areas are given in thousandths of the $2p^{-1}(^2P_{3/2}) \rightarrow 3p^{-2}(^1D_2)$ diagram line area, and the energy scale is adjusted to 203.25 eV, the energy of this transition.

Energy (eV)	Identification	Rel. peak area (10^{-3}) at diff. projec. energies				
		275 eV	300 eV	500 eV	1000 eV	1700 eV
206.3	$2p^{-1}(^2P_{3/2})3d \rightarrow$ $3p^{-2}(^1D)4d\ ^2P, ^2D, ^2F$	54 (9)	28 (4)	5 (2)	8 (2)	7 (4)
208.6	$2p^{-1}(^2P_{3/2})4p \rightarrow$ $3p^{-2}(^1D)4p\ ^2P, ^2D, ^2F$	60 (10)	36 (5)	8 (2)	3 (1)	4 (1)
210.0	$2p^{-1}(^2P_{3/2})4s \rightarrow$ $3p^{-2}(^1D)4s\ ^2D$	41 (11)	18 (4)	8 (2)	5 (2)	5 (1)

At higher projectile energy, despite of the decreasing intensity of the satellite peaks relative to the diagram lines, we could identify more satellite lines. This is mainly due to the decreased continuous background of the scattered and secondary electrons which was partly resulted by the applied low-background triple pass (ESA-21) electron spectrometer.

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Angular distribution of KVV Auger-line intensities from N_2 molecules induced by 1.5 and 2 MeV protons

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The angular distribution of KVV Auger electrons from N_2 molecules was measured at 1.5 and 2 MeV proton impact. The spectra were collected simultaneously at 13 different angles from 0° to 180° with a high resolution electrostatic electron spectrometer (ESA-21). The data obtained by Svensson *et al.* [1] were used for the identification of the Auger lines. The transition energies, the relative intensities and the natural line width (FWHM) of the Auger lines were determined (Víkor *et al.* [2]). The angular distribution of the KVV Auger-lines gives useful information on the molecular orientation at the ion–molecular collisional ionization. We observed significant molecular Auger-line anisotropies, which indicates that the ionization probability of the molecular core depends on the direction of the internuclear axis, relative to the ion beam. It means that the double differential ionization cross section of the homonuclear dyatomic molecule is not isotropic due to the noncentral distribution of the atomic electrons.

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Enhancement of the Auger-line intensity due to the fast proton–neon post-collision interaction

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The angular distribution of the Ne K-$L_{2,3}L_{2,3}$ ($^1D_2$) Auger-line as function of the projectile velocity relative to the beam direction was measured to investigate the fast ion–atom post-collision interaction. A high resolution electrostatic electron spectrometer (ESA-21) was used and the spectra were collected simultaneously at 13 different angles from 0° to 180°. The Ne target was bombarded with proton projectiles from 0.8 to 3.2 MeV. The corresponding projectile velocity relative to the velocity of the Auger-electrons was from 0.73 to 1.47. When the projectile has smaller velocity than the Auger electron, an enhancement is found in the intensity of the Auger line at 0°, due to the focusing effect of the projectile (Víkor *et al.* [1]). It decreases rapidly when the projectile and Auger-electron velocity ($v_p = v_A$) is the same. A similar behaviour of the Auger-line intensity at 0° was predicted by the quantum-mechanical theory of Barrachina and Macek [2].

Furthermore, an angular independent resonant-like intensity enhancement was found around the equal projectile and Auger-electron velocity region. The angular distribution of the Auger-line is very sensitive to the focusing (defocusing) effect which highly depends from the projectile velocity relative to the Auger velocity.

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Si(Li) Detector Lineshapes: Contributions from Atomic Physics and Detector Properties

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The detailed response of two Si(Li) detectors to two different ^{55}Fe sources was studied by least-squares fitting various spectrum models using a new, generalised variant of the GUPIX code. The peak-to-background ratio (10^7) observed for the manganese Kα X-rays is superior in the detectors used here to that observed in a crystal spectrometer, and very large spectrum intensities are recorded. In addition to well-recognised effects such as the intrinsic Lorentzian distribution of an X-ray line and the approximately Gaussian detector response function, the Kα and Kβ peak shapes are also influenced by multiplet structure. The Kβ shape is strongly affected by $3p3d$ exchange coupling, and both Kα and Kβ are influenced by $3d$ spectator vacancy satellites. The flat shelf-like features below the peaks appear to be associated with escape of Auger and photo-electrons, and show hitherto unobserved step-like structure (fig. 1). Using an accurate energy calibration provided by simultaneously recorded rubidium K X-rays, the escape peak energy shift was shown to have the theoretical value of 1.74 keV. The escape peak width was significantly augmented, relative to the value expected for a diagram line at 4.2 keV energy, by shake-off satellites and by an additional component on its low-energy side; this observation explains the widely reported escape energy values in excess of 1.75 keV. Determinations were made of the shape and intensity of the KLL radiative Auger feature, and of the intensity of the KMM feature.

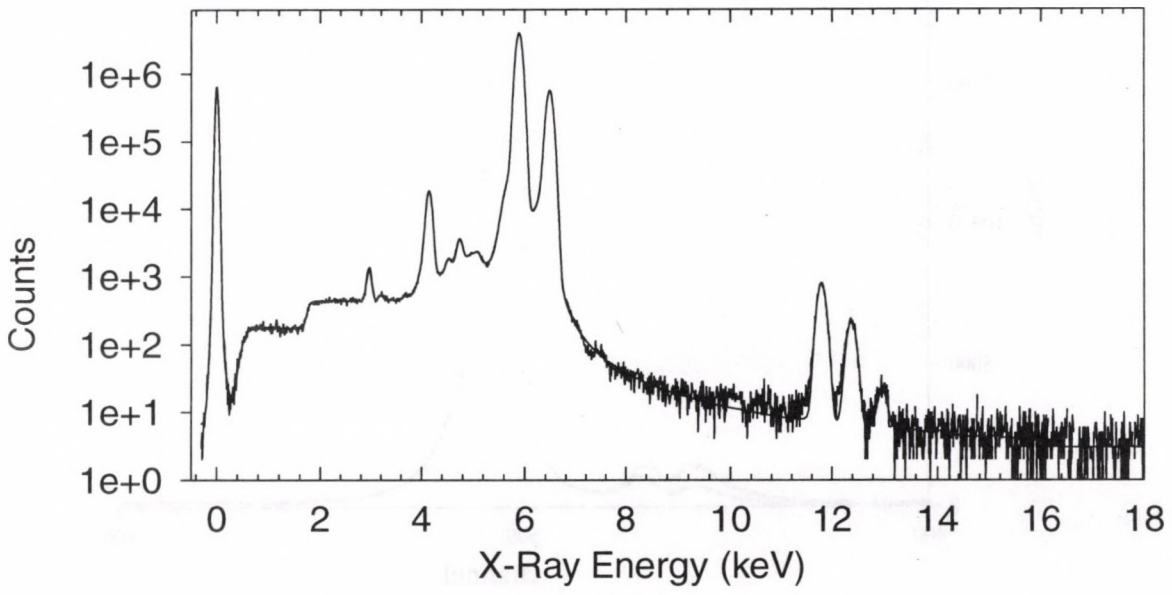

Fig. 1. The spectrum of ^{55}Fe, measured with a Si(Li) detector, with the best fit. The newly observed steplike features are well demonstrated.

This work was supported by the Natural Sciences and Engineering Research Council of Canada.

The effect of the K absorption edge on the intensity of the x-ray lines above and just below the edge energy

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In the papers on the $K\beta_5$ x-ray line intensities ([1] and refs. therein), the correction against the effect of the K absorption edge near to this line is rarely mentioned. The Kβ region of the x-ray spectrum from the Cr metal bombarded by 1.2 MeV protons was corrected in the following way: The absorption curve was calculated by the method described in ref. [2], this curve was convolved with the Gaussian width of the $K\beta_{1,3}$ line, obtained by a fitting of the uncorrected spectrum. Using the convolved absorption curve we made the corrections of the different channel contents. The result is seen on (Fig. 1). It means, that significant enhancement of the $K\beta_5$ line just below, and $K\beta L^n$ x-ray satellite lines above the absorption edge is resulted in such a correction. This can influence the Kβ/Kα ratio of the elements in this *Z* region.

This work was supported partly by the Slovenian–Hungarian Intergovernmental S&T Cooperation Programme, Project No. SLO-9/95 and by the OTKA, grant No. T016636.

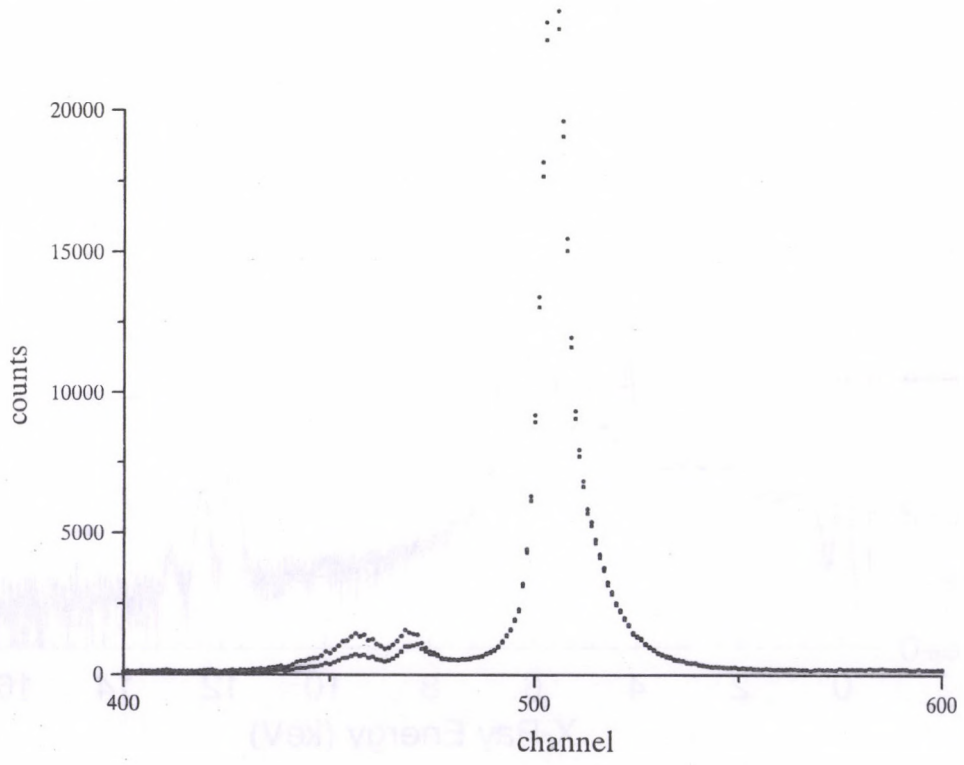

Fig. 1. The corrected (upper) and uncorrected (lower) Kβ spectrum range of Cr

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The Z dependence of the $K\beta_5/K\beta_{1,3}$ x-ray line intensity ratio

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In our recent compilation of the $K\beta_5$ x-ray line relative intensities [1] we gave the experimental $K\beta_5/K\beta_{1,3}$ intensity ratios only to about $Z = 42$. Now we extended this range to $Z = 92$ (Fig. 1). In the cases where the literature gave the $K\beta_5/K\alpha_1$ ratio only, the $K\beta_{1,3}/K\alpha_1$ intensity ratio taken from ref. [2] was used in the transformation. The literature sources of the measured points can be traced from the figures and references of [1], except the case of Xe, where the approximate value was given in ref. [3].

This work was supported partly by the Slovenian-Hungarian Intergovernmental S&T Cooperation Programme, Project No. SLO-9/95 and by the OTKA, grant No. T016636.

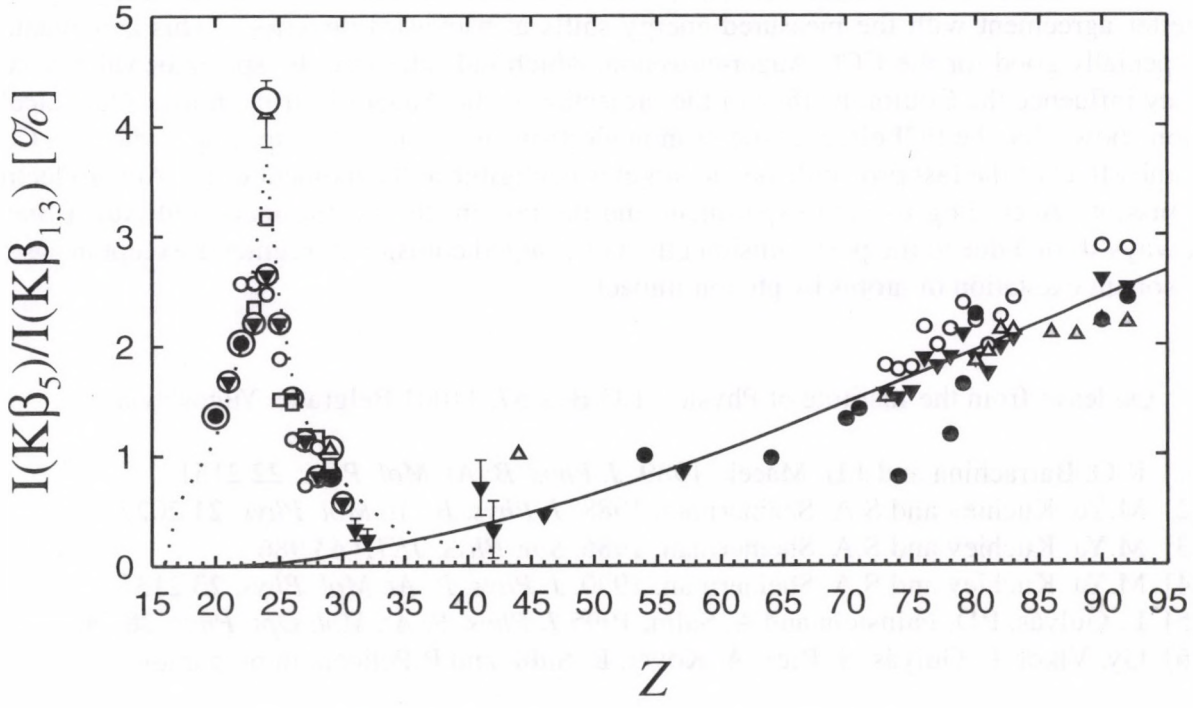

Fig. 1. The Z dependence of the $K\beta_5/ K\beta_{1,3}$ intesity ratio.

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Post-collision interaction between prompt-electrons and Auger-electrons at fast ion–atom collisions

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Quantum-mechanical and semiclassical theories worked out by Barrachina and Macek [1] and by Kuchiev and Sheinerman [2, 3] underestimate the energy shift of the Auger lines caused by the post-collision interaction at backward direction relative to the projectile beam. The reason is the neglect of the Coulomb interaction between the prompt-electrons and the Auger-electron. In the present work we modified the semiclassical theory [3, 4] to include the effect of prompt electrons on the PCI energy shift of Auger lines. The energy and angular distribution of prompt-electrons ejected from a certain shell were calculated by the CDW-EIS theory [5]. The PCI energy shift was calculated for the core–valence–valence (CVV) Ne KL_2L_3 ($^1D_2$) Auger emission for 0.7, 1.5 and 2.0 MeV proton impact, and for core–core–core (CCC) Kr $L_3M_{4,5}M_{4,5}$ ($^1G_4$) Auger line for 2.6 and 3.6 MeV proton impact.

Comparing the values calculated by means of the quantum-mechanical theory [1] and those of our modified semiclassical theory [6] with experiment, the latter one shows a significantly better agreement with the measured energy shifts at backward directions. This agreement is especially good for the CCC Auger-emission, which indicates that the spectator valence-core may influence the Coulomb effect of the projectile on the Auger-electron emitter. Our calculation shows that the PCI effect of the prompt electrons is remarkable, especially when the Coulomb effect of the fast projectile on the target is negligible at the moment of the Auger-electron emission. According to both experiment and the present theory, the measured Auger-line is always shifted due to the post collision effect of charged collisional fragments except in case of resonant excitation of atoms by photon impact.

[†] On leave from the Institute of Physics, P.O.Box 57, 11001 Belgrade, Yugoslavia

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Measurements of Auger spectra of Kr and Xe by electron and proton bombardment

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Measurement on the rare gases krypton and xenon have been done in the frame of the ATOMKI–Oulu cooperation. The electron excited Kr $L_{2,3}$-$M_{4,5}M_{4,5}$, Kr $M_{2,3}$-$M_{4,5}N_{4,5}$ and *M-NN* Auger spectra and the proton excited Kr $M_{4,5}$-*NN*, Xe $N_{4,5}$-*OO* and Xe $M_{4,5}$-*NN* Auger spectra were measured using the high-resolution, angular resolving ESA-21 electron spectrometer. The electron excited spectra were collected using 3.5 keV primary electron energy. Coster-Kronig spectra were also recorded using 1.0 keV primary electron energy. The proton energy was 3.6 MeV.

The purpose of the measurements is to study Auger cascades. We will also search for possible anisotropic angular distributions in these spectra.

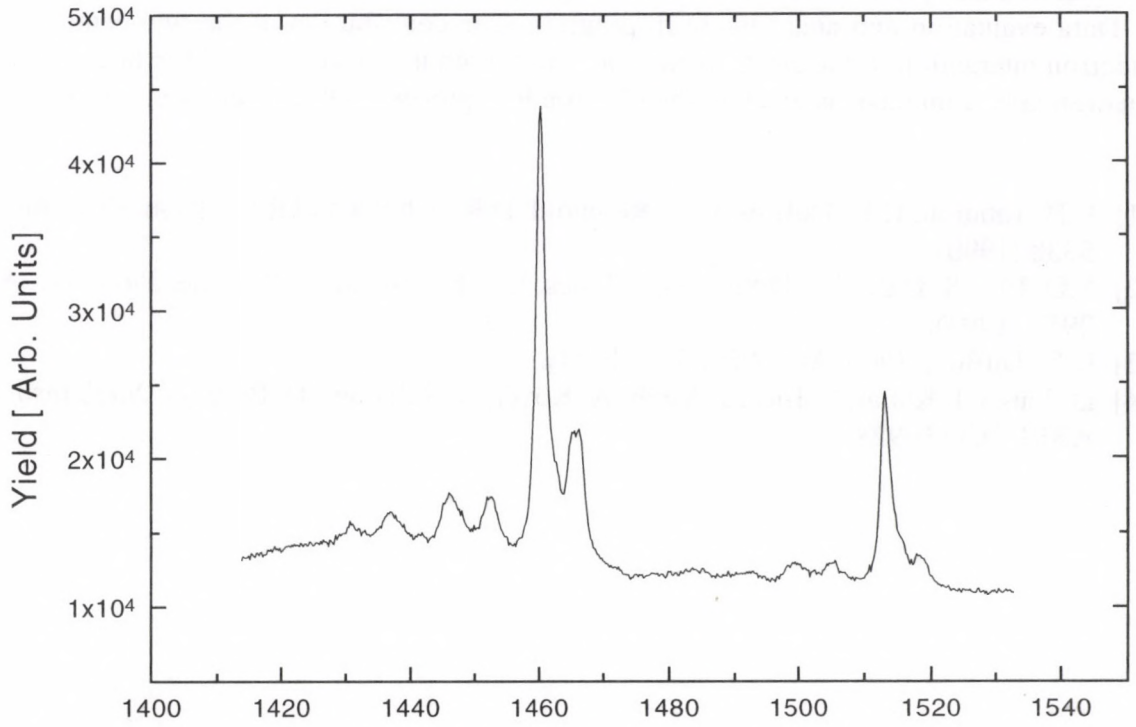

Fig.1. The $L_{2,3}$-*MM* Auger spectrum of Kr excited by electrons of 3.5 keV.

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Electron Loss Contribution to the Continuous Electron Spectra from 150 keV/u C^+N^+ + He Collisions

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The study of ion–atom collisions in the intermediate impact energy range is essential for understanding the collision dynamics. In this region the impact energy is low to fulfill the conditions required for using first order perturbation theories, and high to apply molecular orbital models. On the experimental side, detailed information can be provided by studying the double differential spectra of the emitted electrons.

Relatively few works have been published on this issue for ions heavier than helium (see e.g., [1, 2, 3] and rare of them reported electron spectra taken in a broad angular region.

In the present study the continuous electron spectra stemming from C^+ and N^+ – He collisions were investigated at 100 and 150 keV/u impact energies in the electron energy region of 2 eV – 500 eV at 13 emission angles from 0° to 180° with spacing of 15°. The measurements have been performed by means of a special home-made electron spectrometer which collects the spectra at all angular channels simultaneously (ESA-21) [4]. The first preliminary coincidence measurements between the singly ionized (doubly charged) receding projectile ions and the prompt electrons have also been performed for separating the electrons originating from the electron loss process from the other component of the continuous spectra.

Data evaluation and analysis are in progress. The contribution of the two-center electron–electron interaction to the electron emission from both the projectile and the target is analysed theoretically. Emphasis is given to the electron loss process at backward angles (150° – 180°).

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Time Ordering in Atomic Collisions

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The fact, that the cross sections for two-electron processes in high velocity atomic collisions with charged particles (double ionization, ionization–excitation, double excitation) varies with the sign of the charge was treated theoretically by several groups [1–6]. McGuire [1] has suggested that the interference between the first-order (shake) and the second-order (TS2) amplitudes gives rise of a Z^3 term in the cross section, and this is the cause of the difference.

In a present work [7] we develop a general treatment for the effect of time-ordering in the many-electron processes induced by charged particle impact. We have discussed in more detail the two-electron processes up to second-order. It has been shown that time-ordering is essential in order to obtain odd power Z terms in the cross section which is necessary to get different values for positively and negatively charged projectiles. A second-order calculation is performed for the double ionization of helium. In the present approximation, the electron–electron interaction is taken into account only by the shake-off term. We found that the interference between the shake-off and second-order term is responsible only for a part of the dependence of the cross sections on the sign of the charge of the projectile.

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Double K-shell vacancy production

K. Tőkési and B. Sulik

A three and four-body classical trajectory Monte Carlo (CTMC) method is applied for the study of the K-shell vacancy production in Ni^{7+} + Ti collisions. The cross section ratio of the single to double K-shell vacancy production is obtained and compared to that of experimental result [1, 2].

In both versions of the present CTMC approach, Newton's classical non-relativistic equations of motions are solved numerically for a statistically large number of trajectories for given initial parameters. The initial conditions are set pseudorandomly at relatively large distance from the collision center. The total number of recorded histories was 50000 at each impact energy. The equations of motions are integrated with respect to time as an independent variable by the standard Runge–Kutta method as far as the real exit channels are obtained. In these calculations these were as follow: single ionization (SI), double ionization (DI), single capture to the projectile bound state (SC), double capture to the projectile bound state (DC) and the exit channel when both K-shell electron of the target atom are ejected and at the same time one of them is captured to the bound state of the projectile (DI&C).

In the four-body approximation all the forces acting among the particles are taken to be pure Coulombic ones, and the two-center effect is investigated in a direct way. The interaction between the two active target electrons is neglected throughout the collisions. An effective charge, Z_{eff} = 19.43 of the target nucleus as seen by the active electrons with an ionization energies of 183.0 and 188.8 a.u., respectively, is used for the Ti atom from the Hartree–Fock calculation.

In the three-body approach the Ti ion is represented by a central model potential developed by Green [3]. This potential is used to describe the interaction between the Ti ion core with the projectile and the target electron.

In both CTMC approximation the values for the ratio of the single to double K-shell vacancy production [R = (DI+DC+DI&C)/(SI+SC)] are varying between 7.8% and 8.4% at the impact energy range of 4.7 – 7.71 MeV/amu. The experimental results are changed between 2.25% and 3.2% [1, 2]. The discrepancy can be attributed to the importance of the electron–electron interaction, which was neglected in these calculations.

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Angular distribution of low energy electrons from proton–atom collisions

K. Tőkési and G. Hock

Studies of the angular (energy) distribution of the ejected electrons gives a basic information about the collision dynamics. A sensitive test of the various theories we have at hand when comparing the experimental and theoretical values. The contribution of the low energy electrons to the total ionization cross sections are dominant. Therefore the precise knowledge of the behavior of the slow energy electrons ejected in ion–atom collisions are very important.

In the present study a three-body classical trajectory Monte Carlo (CTMC) method is used to calculate the double differential cross sections of the ionization for proton–H, Ne atom collisions as a function of the electron emission angle. One of the advantages of the CTMC method is that the many-body interactions are exactly taken into account during the collisions. In this way, this approximation is an ideal tool for studying two (or more) center effects affecting the angular distributions of low energy electrons in ion–atom collisions. This approximation is able to utilize various interaction model potentials between the colliding particles on the same footing.

For the proton–H collision study the bare particle Coulomb—we call it as conventional—CTMC method (CTMC-1) was used. In the forward observation angles the agreement between the CTMC-1 and the experimental results seems to be closer than the quantum mechanical predictions. At large scattering angles, at the same time, the CTMC-1 strongly underestimates the cross section values obtained from experiments.

For the proton–Ne collision study both the conventional CTMC method and that using the screening potential modeling the potential of the target nucleus (CTMC-2) were applied. For this collision system, the available theoretical predictions for the angular distribution of the low energy electrons are significantly different from the measured values. For the CTMC-1 model, an expressed strong behavior is found as for the $H^+ + H$ collisions mentioned in the previous case. The minimum value is about at 150 degree similarly as in the experimental results. For the CTMC-2 model, the target nucleus potential is described by a screening function. With the inclusion of the central model potential (Garvey-type) the angular asymmetry transforms into a smoother shape than for the (effective) point-like Coulomb target potential. The cross section curve in the second approximation runs closer to the experimental values.

MATERIALS SCIENCE AND ANALYSIS

Investigation of the ^{3}He induced reactions on natural Ti for the purpose of activation analysis and nuclear implantation*

F. Ditrói, I. Mahunka, S. Takács and F. Tárkányi

Nowadays, the extended use of nuclear methods plays more and more important role in the fields of industrial applications. In the analysis of common and newly developed materials and in testing of their characteristic properties and behavior a very sophisticated tool is given in the hand of the industrial people. This tool is the application of energetic ion beams (IBA) for materials science. In this paper only a part of the above field, the so called Charged Particle Activation is covered.

By bombarding the chosen matrix with ion beams we can use the produced active nuclei for tracing in the matrix itself (elemental analysis) or by hitting it out from the primary target and implanting it into the subsequent secondary target (nuclear implantation). With this method active surface tracing can be produced in very thin (tunable) surface layer, which tracer layer can be used for example for wear measurements. For the planning of the irradiation and calculating the result it is very important to know the cross section of the nuclear reaction in question and also the physical parameters of the implantation.

At present the ^{3}He induced nuclear reactions on natural Ti targets producing short-lived V and Cr isotopes were chosen. For the measurements the well established stacked-foil technique was used on the cyclotron beam of our laboratory. The stacks were so prepared, that after every Ti foil a thin Al foil was placed to catch the recoiled radioactive nuclei from the previous Ti foil. The thickness of the stack (number of Al and Ti foils) was calculated by using the stopping power of the He ions in Ti and Al respectively. The activation of Al itself does not disturb our measurements. Taking appropriate cooling time after the irradiation the foils were measured in pairs to decompose the cross-section curve, and the Al catcher foils alone to determine the implantation versus energy function. The obtained data were compared with the literature and used for calculation of irradiations for wear measurements.

* Partly supported by the IAEA

Recoil implantation for Thin Layer Activation (TLA) and Wear Measurements

F. Ditrói and I. Mahunka

In order to activate very thin layers (several μm or less) of the surfaces of different materials and to introduce activity into non-activable materials, we have introduced the recoil activation by using heavy radioactive products from nuclear reactions. The most commonly used isotopes for recoil implantation are, e.g. the ^{56}Co and ^{7}Be. The nuclear reactions leading to the above isotopes were studied earlier. A special irradiation equipment was developed to avoid the damage of the sample from the direct beam (see Fig. 1). The optimal geometry and the energy and angular profiles of the implantation were also calculated and measured. The list of available reaction and their most important nuclear data are also listed. Special application fields are suggested. As an example the distribution of the implanted activity is shown in Fig. 2 in angular geometry.

Table 1. Nuclear data of the investigated isotopes

Isotope	Half-life (d)	Gamma lines (keV)	Intensity (%)
$^{7}_{4}$Be	53.2	477.00	10.3
$^{56}_{27}$Co	77.3	846.75	99.99
		1037.83	14.0
		1238.28	67.6
		1360.22	4.33
		1771.49	15.7
		2598.58	16.9

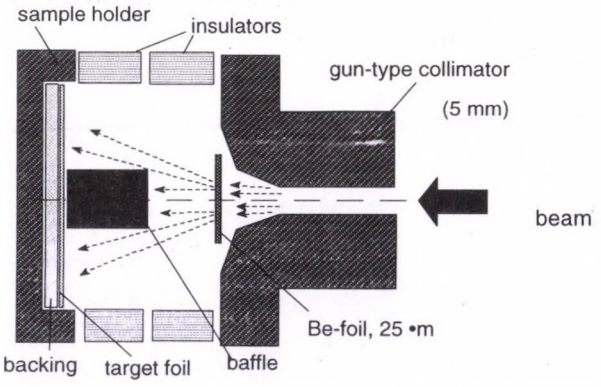

Fig. 1. Irradiation equipment

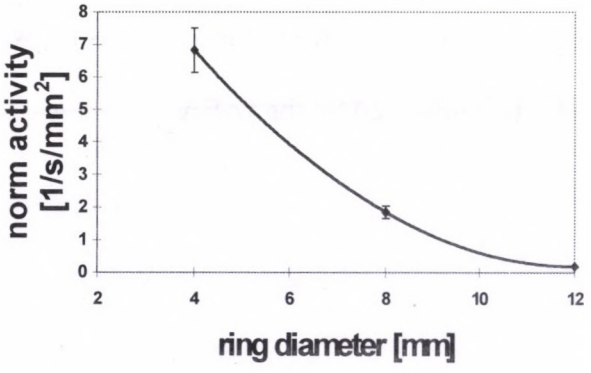

Fig. 2. Normalized activity in Ti rings, irradiation without baffle

Partly supported by the IAEA

Charge Transfer in Au_3Cu and $AuCu_3$ Alloys from Auger Parameter Analysis

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Charge transfer between the constituent atoms of crystals is thought to determine the stability of these structures. The study of the charge transfer and d-d interactions in Au-Cu alloys (a classical example of order-disorder transitions with superlattice phases) led to controversial issues recently [1, 2], generating an increased interest.

Au 4*f*, 3*d*, MNN and Cu 2*p*, LMM photoelectron and Auger spectra were excited by Ag $L\alpha_1$ and Al Kα X-rays from polycrystalline Au_3Cu and $AuCu_3$ as well as high purity Au and Cu metal samples. High energy Auger and photoelectron spectra were measured with a home built electron spectrometer [3]. Al Kα excited core XPS and Auger spectra were measured using a SCIENTA ESCA-300 spectrometer. Alloy-metal Auger parameter shifts were calculated from the measured Auger kinetic and photoelectron binding energies using the definition given by Williams and Lang [4]. For estimating charge transfer from the analysis of the Auger parameter shifts, the method of Thomas and Weightman [5] was used, the model parameters were obtained from atomic structure calculations [6].

The derived values of the transferred charges are very small. In the case of $AuCu_3$ our results are consistent with the charge conservation and show an overall charge transfer of 0.1 *e* to the Au site as it can be expected on the basis of electronegativity arguments and in excellent agreement with the value of 0.11 *e* obtained in recent Mössbauer and XPS studies [1]. For Au_3Cu the value of the transferred charge from our analysis is much smaller (0.04 *e*) than for $AuCu_3$ similarly to previous studies [1]. However, our measurements show vanishing shifts in the Auger parameters of gold, indicating that the effect of the transferred charge on the Au core potential is possibly compensated by on site configuration changes in Au. The present results confirm the applicability and accuracy of the Auger parameter method for determining charge transfer in Au binary alloys.

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Effects of surface loss in REELS spectra of silver

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Precise knowledge of the shape and the intensity of the spectral contribution of the electrons backscattered from solids is essential from the point of view of the determination of the inelastic background of photo- or Auger electron spectra. The Monte Carlo simulation of the electron scattering has been proved to be a very powerful method providing applicable solutions for modeling the inelastic electron spectra and for studying the role of the surface response in REELS spectra.

In this work the spectra of electrons backscattered from polycrystalline silver samples were studied at 200 eV and 2000 eV primary beam energies using the Reflected Electron Energy Loss Spectroscopy (REELS) and for interpretation of the spectra, the Monte Carlo simulation techniques. In the present calculations the surface as well as the bulk energy loss functions derived from optical data, were applied. In our previous work [1] three atomic layers were taken as surface layers for Ag sample in modeling of the backscattered electron spectra. This assumption seemed to be a good approximation in general for simulation of our experimental results, although we had no direct experimental confirmation. The agreement between experiment and theory was less satisfactory at the lower primary energy.

Here new investigations of the effects of the surface energy loss process are presented comparing the experimental and simulated REELS spectra obtained for polycrystalline Ag sample as a function of the energy and irradiation angle of the incident primary beam.

We have shown that mainly three factors contribute to the observed energy distribution of backscattered electrons in REELS spectra: 1. the ratio between the surface and bulk energy losses, 2. surface roughness, 3. surface contamination. It was demonstrated that the backscattered electron spectra is modified strongly at low primary energy because of the surface contamination and the surface roughness. From our studies it can be confirmed that for low primary energies the application of the loss function derived from the experimental REELS spectra leads to the best agreement between theory and experiment, due to the fact that this loss function is representative to the particular sample with given surface roughness and contamination. Therefore the simulation method using this loss function is preferable for determining the inelastic background in XPS, XAES measurements, especially at low primary energies. Our results allow speculations on the possibilities for extracting information on the roughness of the surfaces as well as on the presence and thickness of surface contamination layers by comparing the experimental and simulated backscattered electron spectra. For example for very flat surfaces it is expected to obtain quantitative information on the surface contamination.

[1] K. Tőkési *et al.*, *J. Electron Spectrosc. Relat. Phenom.* **76** (1995) 427

Magnetic Properties of Al–Ni Alloys

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The present calculations were performed using the cluster type DVX_α approximation for spin-polarised electrons developed by Adachi *et al.* [1]. The spin-magnetic moment component σ_0^{j-l} of angular moment l on site j is given by: $\sigma_0^{j-l} = Q_l^{\downarrow}(j) - Q_l^{\uparrow}(j)$, where $Q_l^i(j)$ is the spin-i charge and μ_B is the Bohr magneton. In the case of Al_3Ni the value of the magnetic moment from our calculation is zero, in agreement with the results published earlier [2], as well as with the observation. In the case of $AlNi_3$ alloy our self-consistent calculations give a rather small spin-magnetic moment, for each Ni atom (in μ_B/atom):

$$\sigma_0^{\text{Ni-}s} = 0.033 \qquad \sigma_0^{\text{Ni-}p} = 0.025 \qquad \sigma_0^{\text{Ni-}d} = 0.032$$

through polarisation of the *s, p, d* valence electrons and for each Al atom:

$$\sigma_0^{\text{Al-}s} = 0.027 \qquad \sigma_0^{\text{Al-}p} = 0.075$$

through a small polarisation of the *s* and *p* electrons. All other valence states give a negligible polarisation. Comparing the results of our calculation with the earlier [2] one we find the same polarisation value ($0.032\mu_B$) in the case of Ni-*d* valence electron. The earlier calculation is based on band structure model which use expansions of the Bloch functions in terms of linear combination of energy-independent augmented spherical waves (ASW) [2]. In these calculations [2] the Al-*p* charge through polarisation was found to be $\sigma_0^{\text{Al-}p} = -0.003\ \mu_B$/atom, a value of opposite sign. The experimental magnetic moment is an order of magnitude smaller for $AlNi_3$ than for Ni, this fact is demonstrated with DVX_α calculations. In the case of Al_3Ni the DVX_α calculation gives a zero magnetic moment.

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[2] D. Hackenbracht and J.Kübler, *J.Phys. F*, **10** 427 (1980).

Determination of the inelastic mean free path (IMFP) of electrons in Ge and Si by elastic peak electron spectroscopy (EPES) using an analyser of high energy resolution[$]

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The IMFP of electron is a fundamental material parameter of surface analysis by AES (Auger Electron Spectroscopy), XPS (X-ray Photoelectron Spectroscopy) and EELS (Electron Energy Loss Spectroscopy). In surface analysis, calculated IMFP values are used. Their experimental determination is rather difficult. The IMFP of amorphous Ge and poly-Si was determined by comparing the elastic peak intensity ratios with electrolytic Ni reference sample of 1 nm surface roughness, achieved by dedicated Ar^+ ion bombardment cleaning and examined by STM [1]. Experimental results obtained with a HSA hemispherical analyser ESA-31 developed by ATOMKI. The calculated data was produced by Monte Carlo analysis [2], based on Jablonski's and Joy's differential elastic scattering cross sections and elaborated for the HSA angular window. Due to the high energy resolution of the analyser no spectrometer correction was made. (The relative energy resolution is 0.57%, using different retardations in FRR mode fixing the pass energy to 50 eV in the case of the measured elastic peaks. In this way the 5.7×10^{-3} resolution was increased to 2.85×10^{-4} at 1 keV and 5.7×10^{-5} at 5 keV giving an excellent resolving power). The ratio of the background to the elastic peak was < 1 % at 4 keV. The energy range was extended to 5 keV using Ashley's IMFP data. Reasonable agreement was found with previous CMA results and with data by Ashley [3]. EPES proved to be an efficient tool for IMFP measurements [4].

[$] The paper was presented at an international conference as the first REELS results from Debrecen. Abstracts Book of the *10th International Conference on Thin Films and the 5th European Vacuum Conference*, Salamanca 23–27, September 1996., Spain. Code of the paper MoAV4Po001, p. 44 of the Abstracts Book. The details will be published in *Thin Solid Films and Vacuum* as the Conference Proceedings.

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[1] G. Gergely *et al.*, *Surf. Sci.* **331** (1995) 1203
[2] B. Lesiak *et al.*, *Vacuum* **40** (1990) 67 and **46** (1995) 591
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Determination of the loss function in non-homogenous media for Monte Carlo simulation of the elastic peak

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In majority of cases the specimens studied by AES are non homogenous along the depth. This is especially true in the case of Auger depth profiling. E.g. when we are about to reach the interface the concentration strongly changes along the depth. It is also well known that there is no a simple rule to determine the mean free path for such a non uniform solid. Without knowing the mean free path we can not, however, evaluate our Auger results.

Trying to cope with this problem we have measured the elastic peak during depth profiling and we have also calculated it (the calculation of the elastic peak is easier than that of the Auger peak) by using direct Monte Carlo simulation based on the depth distribution of the elements determined by dynamic TRIM code [1]. For the calculation we used loss probabilities given by simple expressions developed for pure bulk solids.

Now we will report on a more sophisticated new attempt to calculate the loss function. We calculated the dielectric-response function of a non-free electron like compound having surface using molecular-orbital method including electron- correlation. The effects of surface and volume plasmons have been investigated, respectively. The theoretical results of this new method have been compared to that of using Drude–Linhard model dielectric functions. The loss function determined is checked by measuring the elastic peak and its surroundings for well defined Mo/Si alloys. It is also used for the direct Monte Carlo simulation of the elastic peaks during depth profiling.

[1] A. Konkol and M. Menyhárd, *Surf. Inter. Anal.*, submitted

Monte Carlo code for the study of the (e, 2e) process in solids

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In the last years kinematically complete (e, 2e) experiments were published in which the spectral momentum density of valence electrons in solids was measured [1, 2]. In these experiments a high energy incident electron (E_0 ~ few times 10 keV) knocks out a target electron. The scattered and ejected electrons, after passing through the thin target film, are detected in coincidence and their energies and momenta are analysed.

For the understanding of the basic physical mechanism of the (e, 2e) experiments a new Monte Carlo (MC) code was developed and tested last year. The Monte Carlo technique was chosen because it is generally recognized that the MC simulation is very useful tool for studying the electron transport process in solids. In the present approach both the individual elastic and inelastic scattering events in the solid are taken into account. The elastic scattering process is described by the Mott-scattering cross-section obtained from the partial wave expansion method. The inelastic scattering process is described in terms of the dielectric function formalism in which the experimental optical dielectric data is used to describe the electron energy loss function.

A certain depth t, where the (e, 2e) event occurs is described using the uniform distributed random number (R_1) according to $t = R_1 T$, where T means the thickness of the target film. For the description of the collision between the primary incoming and target electron the binary collision model is used. At the beginning of the collision the target electron is assumed to be at rest. The simulation of the outgoing electron trajectories is started from depth t with suitably chosen initial conditions [$(E_f, \theta_f, \varphi_f)$ for the faster electron, and $(E_s, \theta_s = -90° + \theta_f, \varphi_s = 180° + \varphi_f)$ for the slower electron] and the trace of these electrons are followed until they leave the specimen or they loose to much energy to appear in the energy window of the computed spectra. Subsequently the outgoing electron data are sorted with respect to the geometrical conditions of the detectors. For the test calculation we used the same model as described in ref. [2]. for amorphous carbon film. The total number of primary trajectory was 10^8. Our preliminary results demonstrate the validity of the present approximations. Furthermore realistic calculations are in progress, where the calculated coincidence count rate as a function of the target thickness will be compared with the experimental ones.

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[2] M. Vos and M. Bottema, *Phys. Rev.* B **54** (1996) 5969

Magnetic properties of ball milled $Fe_{15}Sb_{85}$

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Mechanical alloying of immiscible or near immiscible elements with ball mill often results in a heterogeneous granular system of the initial components with grain size in the nanometer region. Especially interesting structures can be obtained by milling a magnetic material with a nonmagnetic component together. In such cases the phenomena of giant magnetoresistance (GMR) and superparamagnetism have been observed. We studied ball milled Fe–Sb systems and observed superparamagnetism at 15% Fe content. X-ray diffraction analysis showed no alloying of the two components up to 400 h milling time. The line broadening of Fe and Sb reflections indicated that 400 h milling of the $Fe_{15}Sb_{85}$ powder produced a heterogeneous granular sample that consists of very fine ferromagnetic Fe particles within a nonmagnetic matrix of nanocrystalline Sb. The mean grain sizes were 12.5 nm for Fe and 20 nm for Sb, respectively.

Low temperature magnetization measurements were performed by a vibrating sample magnetometer. Figure 1 shows the variation of magnetization with temperature measured in 0.1 T field after cooling the sample to 5.6 °K in the presence of 0.1 T magnetic field (FC) and without field (ZFC). The shapes of the FC and ZFC curves are characteristic to superparamagnetic granular materials with a distribution of particle sizes. The size distribution of magnetic particles may extend from a few nanometer up to tens of nanometer. The average magnetic moment of particles was estimated from the Langevin fit of the low temperature hysteresis loops which corresponds to a mean particle diameter of cca. 8 nm.

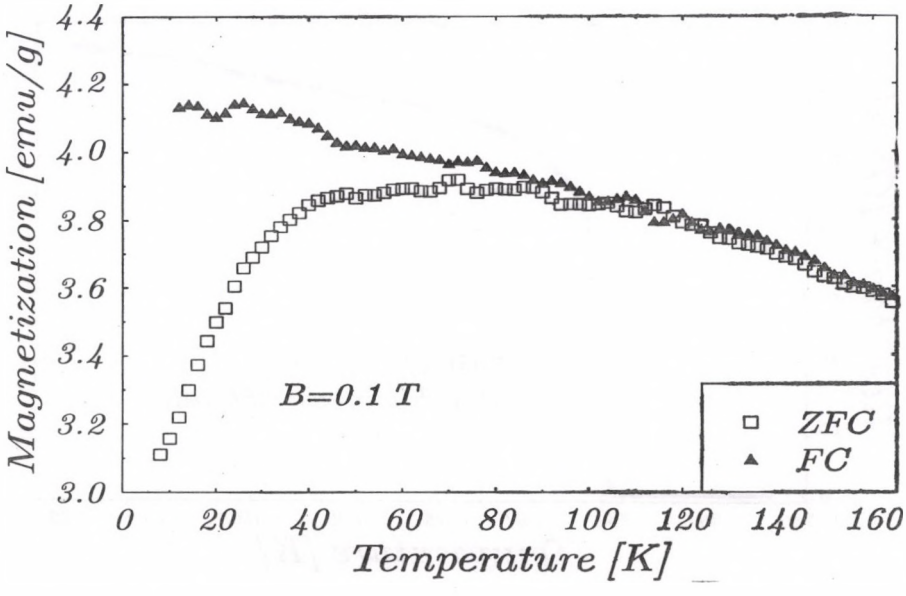

Fig. 1. Temperature dependence of magnetization of 400 h milled sample in 0.1 T field. FC: field cooled; ZFC: zero field cooled.

Deposition of superconducting $YBa_2Cu_3O_{7-x}$ thin films by DC magnetron sputtering

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† Department of Solid State Physics, KLTE, Debrecen, Hungary

$YBa_2Cu_3O_{7-x}$ thin films were deposited on polished single crystal Al_2O_3 and $SrTiO_3$ substrate of size $10\times5\times1.2$ mm^3 by planar DC magnetron sputtering method from a single sintered target, the diameter of which was 45 mm. The film thickness was approximately 200 nm. The sample fixed on a stainless-steel holder was radiation heated by a 250 W quartz lamp. The sample holder position was off axis type, i.e. it was not above the target and the target and holder surfaces were perpendicular to each other. During deposition the substrate was heated to 750 ÷ 800 °C and the temperature was monitored by a calibrated Cr–Ni thermometer. The sputtering gas consisted of 4×10^{-2} mbar Ar and 1×10^{-2} mbar O_2. After deposition the substrate was let to cool down to room temperature in O_2 at 5×10^2 mbar pressure. The presputtering time was 20 hours, after which the sputtered film composition was reproducibly stoichiometric and the pressure value and target potential also converged to steady-state values. The sputtering power (100 W) was constant during deposition times and the target potential varied between 120 and 150 V_{dc}. This arrangement resulted a deposition rate of 0.3 nm/min. The superconducting transition temperature was checked by resistivity measurement using the conventional pulsed dc four probe technique, and the structure of the surface was observed by an AMRAY type SEM. We obtained superconducting phase on $SrTiO_3$ substrate, the resistivity vs. temperature curve is shown in fig. 1.

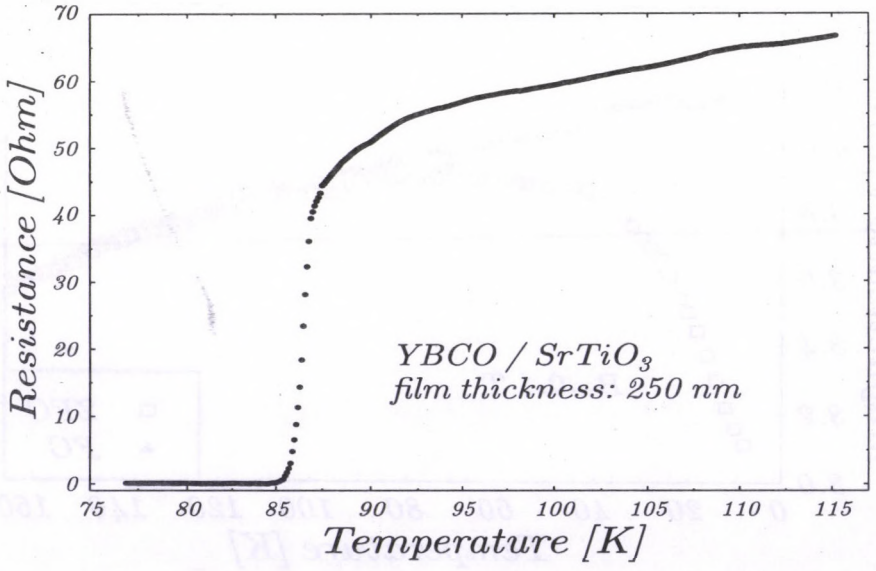

Fig. 1. Temperature dependence of the resistance of an $YBa_2Cu_3O_{7-x}$ thin film

Interlayer coupling of superconducting $Bi_2Sr_2CaCu_2O_8$ near the transition temperature

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Electronic transport measurements make it possible to understand the superconducting – normal phase transition in strongly anisotropic $Bi_2Sr_2CaCu_2O_8$ superconductors. The unusually large anisotropy in the resistivity tensor of these materials prefers the 'flux-transformer' measurements on high quality single crystals [1]. The superconductivity in $Bi_2Sr_2CaCu_2O_8$ originates in bilayers of CuO oriented parallel to the *a–b* plane and the coupling mechanism between these bilayers is Josephson type. At the upper end of the superconducting transition temperature width the Josephson interaction couples the two-dimensional copper-oxid bilayers, and at the lower end the bilayers undergo a Kosterlitz–Thouless-type transition to a zero dissipation state. It means that the *c* direction resistivity (ρ_c) of a single crystal becomes zero at temperatures higher than those of the *a–b* plane resistivity (ρ_{ab}). This shows that 'pancake' type vortex fluctuations dominate the in-plane electronic transport properties near the transition temperature, and this is affected by interlayer coupling. By sending the measuring current into one surface of a single crystal and measuring the voltage both on this (primary) and the opposite (secondary) surface, we can measure the coupling strength between CuO layers.

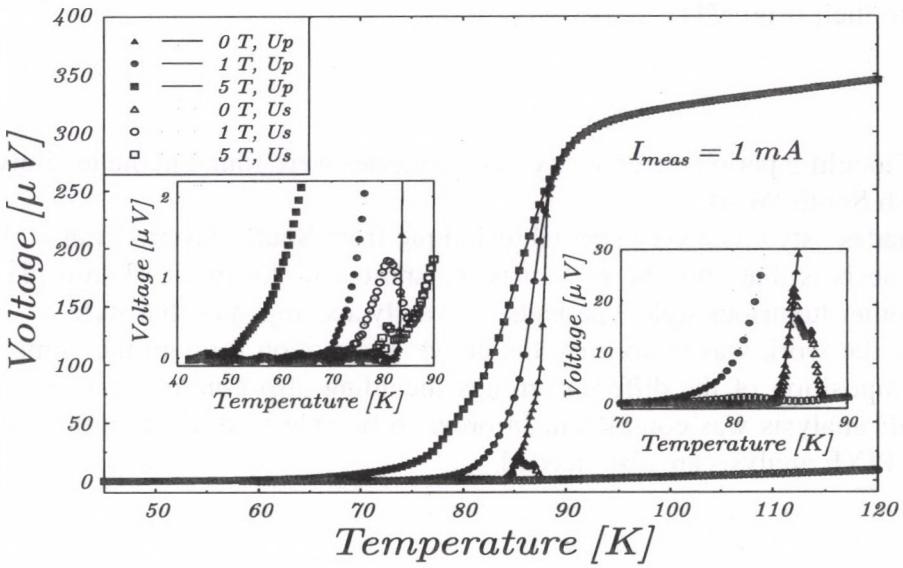

Fig. 1. The temperature dependence of primary (U_p) and secondary (U_s) voltages on a $Bi_2Sr_2CaCu_2O_8$ single crystal

[1] H. Safar *et al.*, *Phys. Rev. Lett.* **72** (1994) 1272.

Applications of Ion Beam Analysis in Archaeometry

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[2] Department of Classical Philology, Lajos Kossuth University, Debrecen

Ring-Stones

In the 17th and 18th century Europe, a great interest developed towards the Greek and Roman art and culture. One of its consequences was that a great number of classicizing style objects or precise imitations of original artefacts were made. Nowadays, in museums they are often mixed with originals. Because of the level of the artefacts, it is very hard to make difference between them even for the experts.

Our investigations were made on ring-stones, being one of the most problematic groups of relics as for their origins. Primarily these were made from minerals or glass pastes. In the later centuries different sorts of artificial base materials also appeared.

We have determined the elemental composition of several artefacts using the nondestructive analytical techniques PIXE and PIGE, both in their conventional (so called "macro") version and in scanning proton microprobe mode. On the basis of elemental composition obtained by the above mentioned analyses unambiguous separation was made among groups of some artefacts related to their origin [1].

Potteries

From the Calcolitic period different styles of potteries were found in the territory of Extremadura (Spanish South West).

The "repujadas" style is a very special technique from South Eastern France. The archaeological hypothesis is that only the style was transmitted in the Iberian Peninsula, but not the artefacts. Another luxurious style, "peinadas", usually accompanies that style.

The aim of the work was to confirm the above assumption through the comparison of the elemental composition of the different groups including also common potteries. Up to now only the PIGE analysis was completed. In order to be able to draw definite conclusions the results of the PIXE analysis are also needed.

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EARTH AND COSMIC SCIENCES
ENVIRONMENTAL RESEARCH

Geochronological studies with the K/Ar method in 1996

K. Balogh, E. Árva-Sós, Z. Pécskay

Review papers appeared on the space and time distribution of Neogene-Quaternary volcanism in the Carpatho-Pannonian Region [1], on the regional metamorphic events in Hungary [2], on K-Ar dating of Neogene-Quaternary volcanic rocks in Romania [3] and on some features of metamorphism in Serbia [4].

Studies on basaltic volcanism were continued in Central and South Slovakia, experiences of dating were summarized, K/Ar and paleomagnetic results were compared [5, 6, 7]. Late Cretaceous to Paleogene ages were measured for the magmatism of the Poiana Rusca Region, Romania [8]. Triassic or older ages with Cretaceous overprint at certain places were measured for the Northern Part of the Ditro Syenite Massif, Romania [9].

Tertiary volcanic rocks were dated from the southern part of the Pannonian Basin, Croatia [10]. Upper Cretaceous (Maastrichtian) age has been established for the polymetallic mineralization in the Čoka Marin volcanic region, Serbia [11].

Upper Oligocene phase of Oligo-Miocene volcanism in Central Sardinia has been dated [12].

Eocene-Oligocene age has been dated for the orogeny in the Inner Dinarides at Busovaca and an approximate value of 200 °C has been measured for the blocking temperature of hyalophane [13].

Ar-Ar dating has been started on metamorphic areas. In Fuerteventura (Canary Islands) Ar-Ar ages suggest Upper Cretaceous-Lower Tertiary age for the beginning of magmatism at Caleta de la Cruz, while in the Esquinzo-valley old K/Ar ages are caused by excess argon.

Ages of (low-grade) metamorphism were measured for a better elaboration of geological background of hydrocarbon prospecting for the MOL Rt. and the time of tectonism has been dated on a geological formation selected for radioactive waste disposal.

Dating of Miocene volcanic rocks in Transcarpathia (Ukraine) has been started. A complex study on the Miocene ignimbrite in the Bükk foreland is in progress.

Provenance of sediments has been studied in the Eastern Alps, in Sicily and in the Mecsek by dating magmatic pebbles in them.

[1] Pécskay, Z., Lexa, J., Szakács, A., Balogh, K., Seghedi. I., Konečný, V., Kovács, M., Márton, E., Kaličiak, M., Széky-Fux, V., Póka, T., Gyarmati, P., Edelstein, O., Rosu, E., Žec, B. (1995): *Acta Vulc.*, **7(2)** 1 (1995)

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[3] Pécskay, Z., Edelstein, O., Seghedi, I., Szakács, A., Kovacs, M., Crihan, M., Bernad. A.: *Acta Vulc.*, **7(2)** 53 (1995)

[4] Fedkin, V., Karamata, S., Cvetković, V., Balogh, K.: Knežević, V., Krstić, B. (eds): *Terranes of Serbia*, Univ. Belgrade, p. 145 (1996)

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[6] Orlický, O., Balogh, K., Konečný, V., Lexa, J., Túnyi, I., Vass, D.: *Geol. Carp.*, **47** 21 (1996)

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[8] Downes, H., Vaselli, O., Seghedi. I., Ingram, G., Rex. D., Coradossi, N., Pécskay, Z., Pinarelli, L.: *Acta Vulc.*, **7(2)** 209 (1995)
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[12] Assorgia, A., Balogh, K., Lecca, L., Ibba, A., Porcu, A., Secchi, F., Tilocca, G.: *Rapporti Alpi-Appennini, Acc. Naz. Sc.*, **14** p. 397 (1995)
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Modelling of soil gas, heat and radon transport in soil

I. Csige,* A. Vásárhelyi, J. Hakl and I. Hunyadi

We calculated the transport of heat, of soil gas and of radon in the soil. Our study was limited to the non-saturated zone, i.e. from the ground-water table to the surface. Soil was considered to be a homogeneous, isotropic, porous medium with respect to the relevant transport parameters (porosity, permeability, heat conductivity and radon diffusivity). Water saturation was allowed to vary as a function of depth, but not as a function of time. Consequently, moisture content dependent parameters (such as thermal conductivity, gas permeability, radon diffusion coefficient) also varied as a function of depth. We assumed a constant flux density of geogas upflow at the groundwater level. The temperature and atmospheric pressure on the soil surface were taken as time dependent boundary conditions. We assumed that the major heat transport process in soil is heat conduction by soil particles and by pore-water. Advective transport by soil-gas motion was neglected because of small heat capacity of gas. We assumed Darcy's low is valid to describe soil gas transport in the soil. Elements of radon transport in soil are its generation rate in the pore space, its transport by diffusion and by advection in the air-filled pore space, its partition distribution between soil-water and soil-air, and its radioactive decay. In figure 1 measured radon activity concentration in soil at 1 m depth is compared to calculated values.

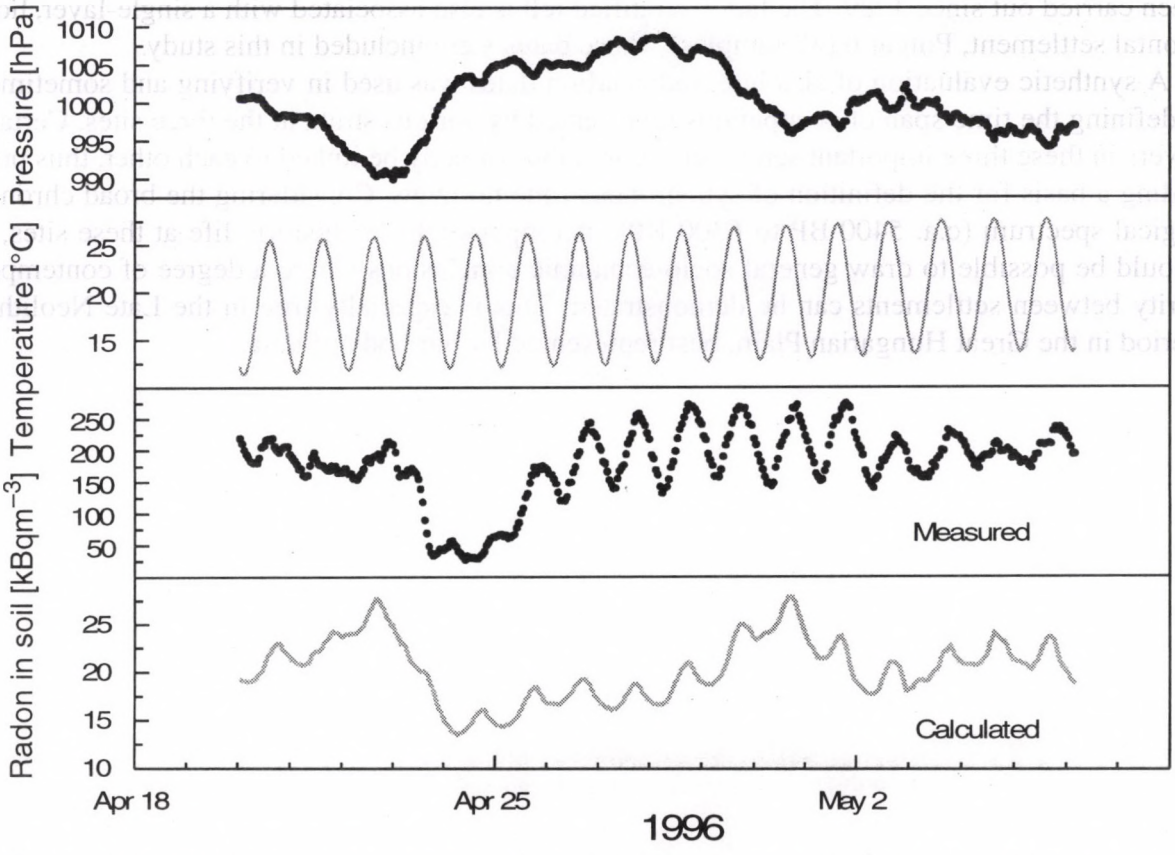

Fig. 1. Variation of atmospheric pressure and surface temperature (upper part), and of measured and calculated radon concentration in soil at 1 m depth (lower part), as a function of time.

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Time spans within tell settlements at three prehistoric sites in Hungary

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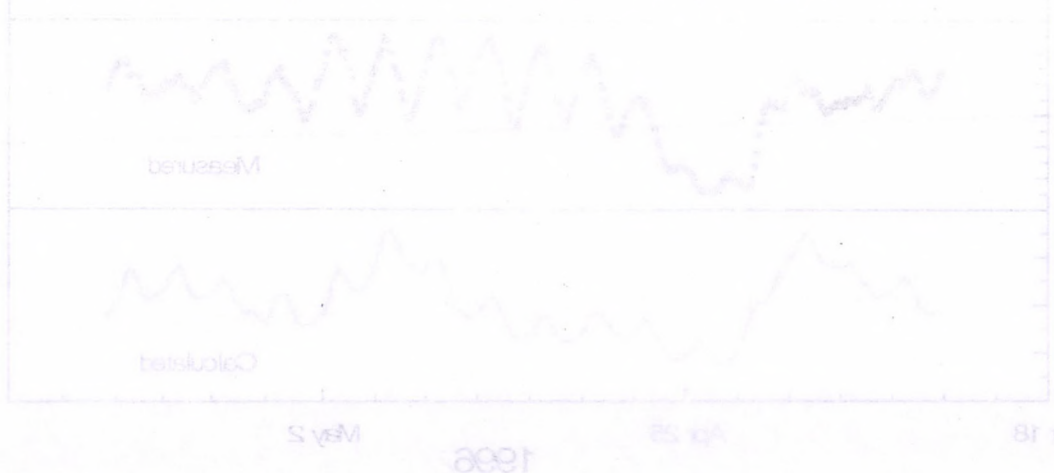
[2] Ferenc Móra Museum, Roosevelt tér 1-3, H-6701 Szeged, Hungary

The Great Hungarian Plain is not only the westernmost edge of the East European steppe belt but also marks the northwestern distribution of Prehistoric tell sites. This type of settlement is characterized by consecutive layers of occupation that form vertical stratigraphies.

Traditionally, relative chronological evaluation is based on the diachronic stylistic/typological evaluation of archaeological artifacts and architectural features. The economic and ethnohistoric interpretation of such data is, however, meaningless without the estimation of absolute time periods that characterized various phases of occupation.

Systematic radiocarbon dating of three major settlements, Berettyóújfalu–Herpály (40 samples), Hódmezővásárhely–Gorzsa (21 samples) and Polgár–Csőszhalom (73 samples) have been carried out since 1989. The latter, stratified tell is also associated with a single-layer, horizontal settlement, Polgár 6 (37 samples) whose dates were included in this study.

A synthetic evaluation of absolute, radiocarbon dates was used in verifying and sometimes redefining the time span of occupations represented by various strata at the three sites. Certain layers in these three important settlements could thus directly be linked to each other, thus providing a basis for the definition of synchronous time horizons. Considering the broad chronological spectrum (c.a. 5400 BP to 6300 BP) encompassed by prehistoric life at these sites, it should be possible to draw general socio-economic conclusions where a degree of contemporarity between settlements can be demonstrated. This is especially true in the Late Neolithic period in the Great Hungarian Plain, best represented by our body of data.



Reconstruction of microenvironmental changes in the Kopasz Hill loess area of Tokaj (Hungary) between 15000–70000 BP

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Kopasz Hill (515 m a.s.l.) is located in the southernmost range of the Tokaj Hills in northeastern Hungary. Kopasz Hill was built up from Miocene (Sarmatian and Pannonian) rhyolite and dacite. The dacite radial ridges constitute lava-flow profiles which overlap each other like rooftiles. The length of lava tongues varies between 0.5–2.5 km with widths ranging between 100–150 m. These eroded lava flows and tongues with a combined area of 16.4 km^2 were covered by loess (12.4 km^2) during the Pleistocene. The loess mantled lava flows rise 120 to 150 m above the floodplains of the Tisza and Bodrog rivers. These lava plateaus are usually covered with a thick blanket (10–15 m, maximum 20 m) of typical loess. Eleven loess profiles were analysed for palaeoecological (geomorphology, sedimentology, geochemistry, isotope geochemistry, quartermalacology, xylotomy, vertebrate palaeontology) and geochronological studies (radiocarbon dating, litho- and biostratigraphy).

Geochronological dates suggest that the loess accumulation and development formed during the last (Weichselian) glacial period between 12000–70000 BP. Based on sedimentological and geochemical analyses the loess was found to be composed of three typical loess strata and two well-developed palaeosol horizons. Biostratigraphical data show that the lowest loess layer was formed between 50000–70000 BP during a cool and dry climatic phase when forest steppe vegetation dominated in the Kopasz Hill area. In this period the first Central Asian cryoxerophillous mountain elements occurred in the analysed region but the survival of several Central European closed-forest species (e.g. Clausilia dubia, Vestia turgida) suggests that local environmental factors such as the relatively humid and temperate microclimate may have produced a refugial area for forest biota.

On the surface of the lowest loess layer, a palaeosol developed between c. 40000–50000 BP. Geochemical evidence from this palaeosol suggested that the mineral composition changed. An increase in clay minerals, especially in the kaolinite content may be an indication of a more humid and warmer climatic phase when the chemical weathering process was more intense than during the loess development period.

This palaeosol layer was buried by a new loess layer which developed between 32000–40000 BP. The decrease in the clay content and a new migration of cold resistant faunal elements are reflections of a new change in the climate and environment. Chemical weathering processes decreased while dust accumulation, the diagenesis, got underway in a cooler and drier climatic phase.

Based on geochemical, sedimentological and radiocarbon data from the surface of the middle loess layer, a new, upper palaeosol horizon was found to have developed between 28000–32000 BP. Molluscs preferring a mild climate were found in this layer which suggests that this phase was wet and relatively temperate. Under interstadial climatic conditions, an intense chemical process started in the region analysed here. The process underwent a change about 28000 years ago when the kaolinite content decreased suddenly and some cold resistant faunal elements appeared with a number of macrocharcoal remains. Charcoal samples from nine sites were dated by radiocarbon analyses. These results reflect the presence of a charcoal rich hori-

zon which developed between 26000–28000 BP. Picea type macrocharcoal remains were found only in the northern profiles of the hill while Pinus silvestris remains were found solely in the southern profiles. This difference in composition of the fossil taiga vegetation indicates a strong microclimatic effect during this time. In the macrocharcoal rich layer, dramatic chemical changes were detected. The results suggest that a podzol or podzol-like soil horizon developed during this phase. The occurrence of macrocharcoal remains indicated that this taiga forest was cyclically burnt during the interstadial/stadial transition which took place about 26000–28000 years ago.

Chemical and sedimentological results show that the chemical weathering process decreased about 26000 BP and loess formation got underway again. Open habitat and cryoxerophillous faunal elements (Microtus gregalis, Allactaga sp. Lagurus sp. and Vallonia tenuilabris) dominated at the beginning of this loess development phase. The palaeoecological results suggest that a cold and dry steppe developed in the region but that the presence of some of the mollusc species preferring forest habitats indicate that there were also some stands of trees. Based on quartermalacological and xylotomic results, the best refugia for trees developed in the northern part of the analysed area where there was a borderline between loess sediment and an ancient floodplain sediment. The forest elements expanded out from this region twice (between 21000–23000 BP and 16000–18000 BP) which indicate two strong climatic and environmental changes during the time of the last loess development.

Comparison of piezometric heads forecasted by deterministic model MODFLOW and neural network: a case study in an aquifer along the Danube river near Paks, Hungary

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The studied aquifer situates along the Danube river near village Paks, Hungary. The water flow in the sub-surface layers is controlled mostly by the Danube river and some artificial lakes. The modelled area is approx. 20 square kilometres. The upper sandy layer of the aquifer is 12 m thick (conductivity is in the horizontal directions $(K_x, K_y) = 10^{-5}$ m/s and in the vertical $(K_z) = 10^{-6}$ m/s, specific storage $S_s = 0.005$ m^{-1}, specific yield $S_y = 0.25$, porosity $n = 0.35$). Below this there is a sandy gravel layer of 6.5 m thickness $(K_x, K_y) = 8\times10^{-4}$ m/s, $K_z = 10^{-4}$ m/s, $S_s = 0.0005$ m^{-1}, $S_y = 0.20$, $n = 0.30$). In the water flow is more intensive in the gravel layer of 21.5 m thickness $(K_x, K_y, K_z) = 10^{-3}$ m/s, $S_s = 0.0001$ m^{-1}, $S_y = 0.15$, $n = 0.25$. The first impermeable clay layer below that is not continuous and the area is characterized by upwelling of water through this layer. Monthly values of piezometric heads of more than 50 observation wells as well as levels of Danube and monthly average of precipitation from the period 1986–96 were used for modelling the water flow in the area. The paper presents the comparison between piezometric heads calculated by deterministic models like MODFLOW with those obtained by an artificial neural network using just rainfall data and Danube levels in the investigated area. 10 years of rainfall measurements from a station as well as the Danube levels and the corresponding piezometric heads, were used to train the network and to tune the deterministic model parameters. Both methods were then tested on a year, where the rainfalls together with the Danube levels were given as input and the models were asked to forecast the monthly averaged heads in wells. The neural network proved to have several advantages over the deterministic models. The first advantage lies in that the deterministic model needs a lot of data for the calibration of the parameters as well as information on the aquifer structure. On the other hand, the neural network uses only the heads data to calibrate the weights. This means that the neural model is not only more compact and easier to build, but also more widely applicable. The second advantage is that the neural network, once trained, is faster at predicting the heads values. The drawback of a neural approach lies in that no deeper understanding on the physical phenomena is gained from using a neural network, since it resembles the behavior of a black-box method.

Micro-PIXE characterization of volcanic individual aerosol particles from a Chilean eruption

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Volcanic eruptions represent a natural source of aerosol particles which releases nearly half of the continental dust flux into the atmosphere. Due to the role they play in global climatic changes and the importance of the environmental changes caused volcanic emissions are the subject of regular analytical investigations. In some of these works PIXE is used as analytical method.

Aerosol emission during major volcanic activities around the Chilean eruption site Lonquimay in the years 1988–90 were the subject of PIXE analytical works performed by Morales *et al.* [1]. The aim of such work could be the investigation on the nature of particles in terms of their elemental composition, presence of separate groups of different composition by statistical dissimilarity analysis, and morphological information related to crystalline structure. Gas-to-particle conversion could be verified by the observation of sulphur appearing in coarse and/or fine mode aerosol particles, as well.

In the present work comparative PIXE and micro-PIXE measurements have been performed here on the volcanic aerosol samples collected by the Chilean group. A set of aerosol samples has been placed at our disposal for individual characterization of the particles in the frame of a joint work. Due to the limit set by the beam size of 1 μm to be obtained from our micro-PIXE focusing system structural information from micro-PIXE measurements were received on coarse fraction samples only. However, spectra representing unresolved total scanning area were taken on fine fraction samples, as well.

From our experimental data the following conclusions can be drawn:

- The average features appearing in the macro-PIXE measurements on Lonquimay volcanic samples by Morales *et al.* are regained in our micro-PIXE measurements.

- While the majority of sulphur appears in the fine fraction aerosol (where no structural information can be obtained by the micro-PIXE arrangement, so we only reached here average concentrations over the scanning area) well measurable sulphur contents have been found in individual aerosol particles appearing in the sulphur maps taken on coarse aerosol samples, as well. The maps and the respective concentration values obtained indicate the conversion of gaseous sulphur into particles. Similar statement can be made on the behaviour of chlorine.

- The observation of two separate types of particles clearly confirms through their different content of calcium relative to iron the main conclusion of an X-ray diffraction study performed by the Chilean group on volcanic ash powder. They found the groups Sodium-Calcium Feldspar and Aluminium Augite as the principal crystalline structures present in the ash. In the original structure (Ca, Na)(Si, $Al)_4O_8$ of Sodium-Calcium Feldspar Fe is absent except that Al can be replaced by Fe to a low extent, rarely more than 5%. In the contrary, Fe is one of the principal constituent of Aluminium Augite Ca(Mg, Al, Fe)SiO_6. The separate particle groups observed in micro-PIXE and resolved in dissimilarity analysis represent these separate groups of crystalline structure.

- An attempt has been made for obtaining micro-PIXE morphological information on selected particles. It was found, however, that for such investigations the present technical level should be improved towards better stability of the sample against deformations caused by the

heat deposited by the beam. With increased need of higher statistics in this application the deformations which remain insignificant during concentration measurements may reach a level where structural information can be smeared out with increasing bombarding time. More, a combination of micro-PIXE with SEM methods seems to be desirable.

This work has been partly sponsored by the International Atomic Energy Agency (CRP, 7257/RB), and National Foundation for Scientific Research (OTKA No. T017040).

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Aerosol Sampling and Analysis by PIXE

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In this work, data obtained by PIXE analysis of aerosol samples collected between February 9, 1995 and February 10, 1996 (86 samples) in a rural sampling site are shown. This place is located in the Hortobágy National Park roughly 160 km east from Budapest and 60-km northwest from Debrecen. Samples were collected 2 times a week with a "Gent" stacked filter unit (SFU) sampler operating 24 hours duration. Coarse particles with EAD (equivalent aerodynamic diameter) of 2-10 μm have been collected on 8 μm pore size, 47 mm diameter Nuclepore PC filters, and fine particles with EAD < 2 μm, on 0.4 μm pore size Nuclepore PC filters. The total airborne particulate mass has been measured, too, using a Sartorius microbalance.

The 2 MeV energy proton beam of the 5 MeV Van de Graaff accelerator of the Institute has been used for PIXE analysis. Spectra have been evaluated with the PIXYKLM programme package. Concentrations of 16 elements were detected on coarse mode: Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Cu, Zn, Ba, and Pb. On the fine mode samples there was no P, but in 19 cases Br, has been found and on a few sampling days, As was above its detection limit (4 ng/m^3).

Results of statistical evaluation are shown in Table 1. below. The "Sum" in the table is the sum of the mean elemental concentration measured by PIXE. PM10 and PM2 are the total airborne particulate mass obtained by weighing filters before and after sampling.

Table 1. Statistical analysis of rural atmospheric aerosols sampled between February 9, 1995 and February 10, 1996 in Hortobágy National Park, Hungary (all values are given in ng/m^3)

coarse mode			fine mode		
Element	Mean	St. dev.	Element	Mean	St. dev.
Al	172	194	Al	81	41
Si	749	1110	Si	133	152
P	17	11	S	2006	1231
S	318	310	Cl	15	11
Cl	22	24	K	261	224
K	160	154	Ca	47	41
Ca	234	252	Ti	4	3
Ti	22	35	V	3	2
V	2	1	Cr	2	2
Cr	6	9	Mn	5	3
Mn	7	7	Fe	94	79
Fe	273	310	Cu	3	2
Cu	3	2	Zn	22	19
Zn	9	8	Br	5	2
Ba	10	5	Ba	7	3
Pb	15	11	Pb	24	21
Sum	2018		Sum	2713	
PM10	9583	6685	PM2	19581	11324

This work has been partly sponsored by the International Atomic Energy Agency (CRP, 7257/RB), and National Foundation for Scientific Research (OTKA No. T017040).

BIOLOGICAL AND MEDICAL RESEARCHES

Research of [^{11}C]CGP 12177 with High Specific Activity

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S-(3'-t-Butylamino-2'-hydroxypropoxy)-benzimidazol-2-[^{11}C]one or shortly S-[^{11}C]CGP 12177 is an important radiopharmaceutical [1, 2] to study beta-adrenergic receptors in vivo by Positron Emission Tomograph (PET). Since in Groningen many problems occured with respect to a low specific activity, research was initiated to trace the way of introduction of carrier.

The product is analysed by HPLC (high pressure liquid chromatograph) coupled with UV and radiodetectors after every synthesis. The system is able also to test the carrier without irradiation ("cold" synthesis) by using only UV detector.

The first step of the synthesis is the production of $^{11}CH_4$. After trapping in Porapak Q, $^{11}CH_4$ was mixed with Cl_2 gas in a homogenisation cell. In the radioactive ("hot") experiments, compared to the "cold" experiments when the system was used only from this homogenisation step, the specific activity did not change substantially, so the carrier C-compound was picked up practically beginning from the homogenisation step and not from the target or its trapping systems.

The $^{11}CCl_4$ was produced from $^{11}CH_4$ by $CuCl_2$ on pumice base at 400 °C. Removing the pumice column the quantity of the carrier CGP did not change substantially. So, the main part of the carrier CGP was not produced from the pumice matter.

The $^{11}COCl_2$ was produced by iron catalyst on 300 °C from $^{11}CCl_4$ by addition O_2 gas flow. At the "cold" experiments, removing the iron from the column there is no any carrier formed at room temperature. Using only heating without iron filling, the carrier CGP remained proving that the carrier was not produced from the iron matter and there was no need to use the iron catalyst to get carrier CGP . Accordingly we have such a starting carrier C-compound which transformed into phosgene also without iron catalysis but only on high temperature (300 °C).

At the last step of the synthesis the unreacted Cl_2 gas was trapped by an antimony column and the $^{11}COCl_2$ was trapped into the diamino-precursor solvent to form [^{11}C]CGP.

Summarizing the experiences mentioned above, the pumice and the iron matters were not sources of the carrier C-compounds.The problem can be the impurity of Cl_2 gas. On the other hand, further possible problem can come from the incorrect Cl_2 injection carried out by hand. By this way the chemical system could pick up some other carrier C-compounds from the air. One of these compounds may be CO_2. Nevertheless using $^{11}CO_2$ instead of $^{11}CH_4$ for the synthesis, there was no any radioactive [^{11}C]CGP product detected, proving that the C-carrier compound was not from CO_2. In further examinations the gases (first of all the Cl_2) used in the experiments will be analysed to search the starting carrier compounds.

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[2] P. Landais and C. Crouzel, *Appl. Radiat. Isot.* Vol. 38. No. 4 297 (1986).

Preparation of [^{11}C] Labelled Methyl Iodide Using HI on Alumina

Z. Kovács, É. Sarkadi, L. Andó and F. Szelecsényi

In the preparation of ^{11}C-labelled radiopharmaceuticals the main reaction route is the methylation of precursors with $^{11}CH_3I$. Since the first preparation [1] several modified methods have been developed using the $^{14}N(p, \alpha)^{11}C$, $^{11}C + O_2 \rightarrow {}^{11}CO_2$ production method. The $^{11}CO_2$ is trapped and then reduced with $LiAlH_4$ resulting a complex.

In further steps of the $^{11}CH_3I$ synthesis there are two different chemical methods to get the product. In one of them the dried complex is treated with HI where, after hydrolysis, the $^{11}CH_3OH$ reacts with the HI boiled under reflux conditions [2]. In the other method, other compounds have been introduced to iodinate the radiomethanol. Holschbach and Schüller [3] used a dynamic system to transport the $^{11}CH_3OH$ through triphenylphosphine diiodide on alumina support with carrier gas at 160 °C. In our experiments $^{11}CH_3I$ was prepared using a HI impregnated Al_2O_3 column for iodination of $^{11}CH_3OH$.

In our institute a remote controlled system was built to produce $^{11}CH_3I$. $^{11}CO_2$ is reduced by $LiAlH_4$ in tetrahydrofuran to a complex. After evaporation of the solvent, phosphoric acid is added to hydrolyze the complex to $^{11}CH_3OH$ [4]. The $^{11}CH_3OH$ is distilled out at 160 °C and led through the glass tube containing HI/Al_2O_3 at a He flow. After going through the trap for cleaning the product is collected in the other reaction vessel in a solvent depending on the further labelling procedure. The conditions of preparation and the temperature dependence of conversion were measured. At optimal condition, 200 µl 57% HI/700 mg Al_2O_3 mixture composition, the conversion yield is 97±2%.

[1] D. Comar, M. Mazière, *Radiopharm. and Lab. Comp.*, IAEA, Vienna, Vol. 1, p. 461 (1974).

[2] C. Marazano, M. Mazière, G. Berger, D. Comar, *Int. J. Appl. Radiat. Isot.* **28,** 49 (1977).

[3] M. Holschbach, M. Schüller, *Int. J. Appl. Radiat. Isot.* **44,** 779 (1993).

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Production of ^{15}O-labelled butanol and water

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In January 1994 a new PET-camera was installed in Hungary. It is the first one in Eastern Europe. After developing the automated production of ^{18}F-labelled FDG and ^{11}C-labelled methionine we started the investigation of the ^{15}O-labelling. The n-[^{15}O]butanol and [^{15}O]water are the most commonly used flow-tracers in positron emission tomographic measurements. The routine rapid and sequential production of these two radiopharmaceuticals requires fully automatization of the labelling processes. Being both of these compounds human drugs the quality requirements, including radionuclidic-, radiochemical-, chemical- and pharmaceutical purity are very strict [1].

On the basis of the $^{14}N(d, n)^{15}O$ nuclear reaction the irradiation of N_2 target gas was carried out with deuteron beam using the 10 MeV on-target energy [2]. The irradiated gas is produced in batch mode and it can choose the way of the preparation of either [^{15}O]water or [^{15}O]butanol. [^{15}O]water production is based on the catalytic burn of the irradiated gas containing [^{15}O]O_2 with hydrogen. The panel for synthesis is equipped with a gas-flow controller, a thermoregulated furnace, appropriate number of solenoid valves and an own-developed radioactivity detector. The n-[^{15}O]butanol can be synthesized in the reaction of [^{15}O]O_2 with tributyl-borane on alumina support, and the [^{15}O]butanol is separated from the side-products on two C18 columns. The system contains three own-developed radioactivity detectors, the gas-flow controller and two sets of cartridges for the sequential production. Both panels are remotely controlled by PC. The software is developed in Borland C++.

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DEVELOPMENT OF METHODS AND INSTRUMENTS

Radiation tolerance tests for CERN LHC experiments

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In the frame of CERN RD-16 (FERMI) and RD-40 (Q-CAL) projects, neutron and gamma radiation tolerance tests of different integrated circuits (PSA-ADC and ADS 821 (Burr–Brown)) and a PM-tube (Hamamatsu R5600) were carried out at the irradiation facilities of the ATOMKI in 1996.

Tests of functional units of the FERMI microsystem were continued. A 200 kRad gamma dose resulted in a general failure of the PSA-ADC circuit due to the total dose effect. No degradation of dynamic parameters of the ADS 821 was observed in the range up to 10^{14} n/cm^2 neutron flux.

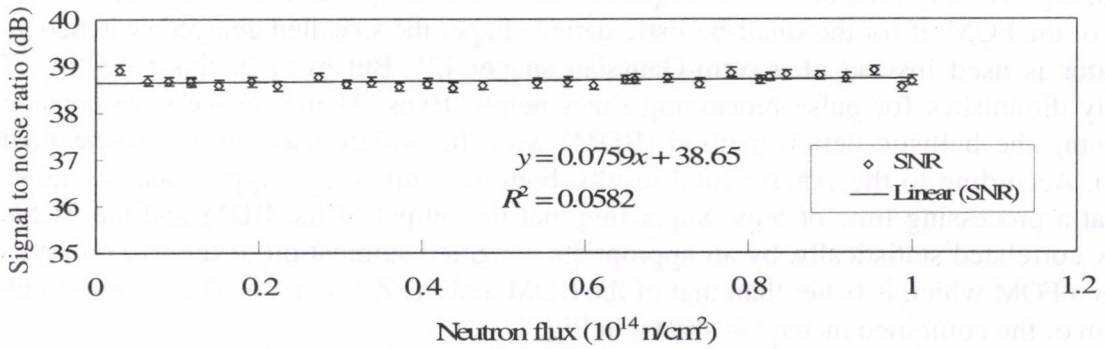

Fig. 1. Signal-to-noise ratio (SNR) of the ADS 821 vs. neutron flux.

Preliminary irradiation tests of components to be used in Very Forward Calorimeters (VFC) in LHC detectors were also conducted for the CERN RD-40 project.

VFCs in LHC detectors should cover the pseudorapidity range from $\eta = 2.5$ to at least $\eta = 5$ in order to compute missing transverse energy and to enable jet tagging. Operation at such high rapidity requires the use of a calorimetry technique that is fast and insensitive to neutron and gamma background. This can be accomplished through the Quartz-Calorimeter (Q-Cal) concept where silica core fibers resistant to the GRad radiation level are embedded into an absorber. In this calorimeter, the shower particles produce light through the Cherenkov-effect generating a signal of less than 10ns duration. Unique to this new technology, the visible energy of hadronic showers has a transverse dimension nearly an order of magnitude smaller than that in conventional calorimeters enabling precise spatial resolution, shaper isolation cuts and better jet recognition against the minimum bias events background. Because most radioactive decays and neutron interactions produce particles below the Cherenkov-threshold; therefore, this calorimeter is intrinsically insensitive to radio-activation background.

The purposes of the RD-40 project are: 1) detailed study of the performance of different kinds of silica fibers in intense radiation environment, 2) study of customized UV-photodetectors, 3) construction and beam testing of suitable electromagnetic and hadronic calorimeter prototypes with all the features required for a VFC (radiation resistance, speed, spatial resolution, transverse energy measurement and implementation of a trigger).

The dark-current of the PM-tube was measured as a function of the neutron flux. Photometry measurements and gamma-irradiation studies are in progress in cooperation with the Institute of Experimental Physics of the Lajos Kossuth University, Debrecen.

Designing the VXI variant of the particle discriminator used with CsI(Tl) + PIN photodiode scintillation detector

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The VXI variant of the particle discriminator to be used in the EUROBALL is under construction. It was targeted that its pulse processing time should be the same as that of the existing Ge signal processors. This means 5 μs analog processing time and since the CsI detector is more than an order of magnitude slower than Ge detectors, fulfilling this requirement is very difficult if we want to reach an acceptable figure of merit (FOM) of the particle discrimination. Originally for the particle discrimination we used the so called ballistic deficit method (BDM) [1]. The pulse processing time of this technique can be significantly reduced without drastic degradation of the FOM, if for the small-ballistic-deficit shaper the so called delayed switched gated integrator is used instead of a semi-Gaussian shaper [2]. But even in this case the FOM strongly diminishes for pulse processing times below 10 μs. Therefore we have considered combining the ballistic deficit method (BDM) with the widely used zero crossing method (ZCM). According to the experimental results, both techniques give approximately the same FOM at a processing time of 5 μs. Supposing that the output of the BDM and the ZCM are weakly correlated statistically, by an appropriate weighted summation of the two outputs one can get a FOM which is better than that of the BDM and the ZCM alone. The simplified block diagram of the combined method is shown in Fig. 1.

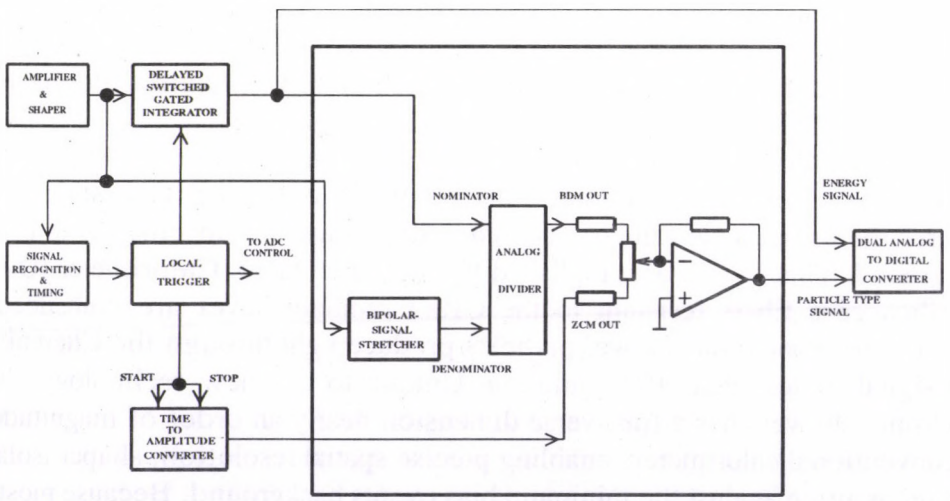

Fig. 1. Simplified block diagram of the particle discriminator combining the ballistic deficit method (BDM) and the zero crossing method (ZCM). In the realization of the BDM the nominator input of the analog divider is the small-ballistic-deficit unipolar signal and the denominator input is the large-ballistic-deficit bipolar signal. In this case the BDM output as a function of the signal shape (rise time) will vary in the same direction as the output of the ZCM.

This work was supported by OTKA (T7481) and by PECO (ERBCIPD CT 940029).

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[2] J. Gál *et. al.*, ATOMKI Annual Report 1994 (1995) 80

Improved wrapping of ancillary scintillation detectors for EUROBALL

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Scintillation detectors for charged particle (CP) discrimination necessitate a very careful optimization of the light reflection wrapping, due to the rather inhomogeneous light collection in this case. To obtain good energy resolution and peak shape, such an optimization was carried out [1] on the detectors of the 25-element ChessBoard [2] (Debrecen–Stockholm) system intended as an ancillary detector to be used inside EUROBALL [3]. Recently a similar optimization was done on the elements of the future Diamant-II 4π scintillation detector system, a combination of DIAMANT [4] (Bordeaux) and the ChessBoard systems, dedicated to light-CP discrimination, also with EUROBALL.

For the first 34 detectors completed, the light collection and energy resolution measured for 5.5 MeV α particles are $70 \pm 3\%$ (380 keV Si equivalent energy) and $2.4 \pm 0.2\%$, respectively. The best performance obtained is shown in the figure for ^{232}U α-source. Peak shapes in this spectrum can be best described with a $1/(E_0 - E)^{1-\alpha}$ function convoluted with a Lorentzian and a Gaussian. For the 8.78 MeV peak the asymmetricity is only $\alpha = 0.02$, while the Lorentzian and Gaussian widths are $2\Gamma/E_0 = 0.005$, and $2.35\ \sigma/E_0 = 0.019$.

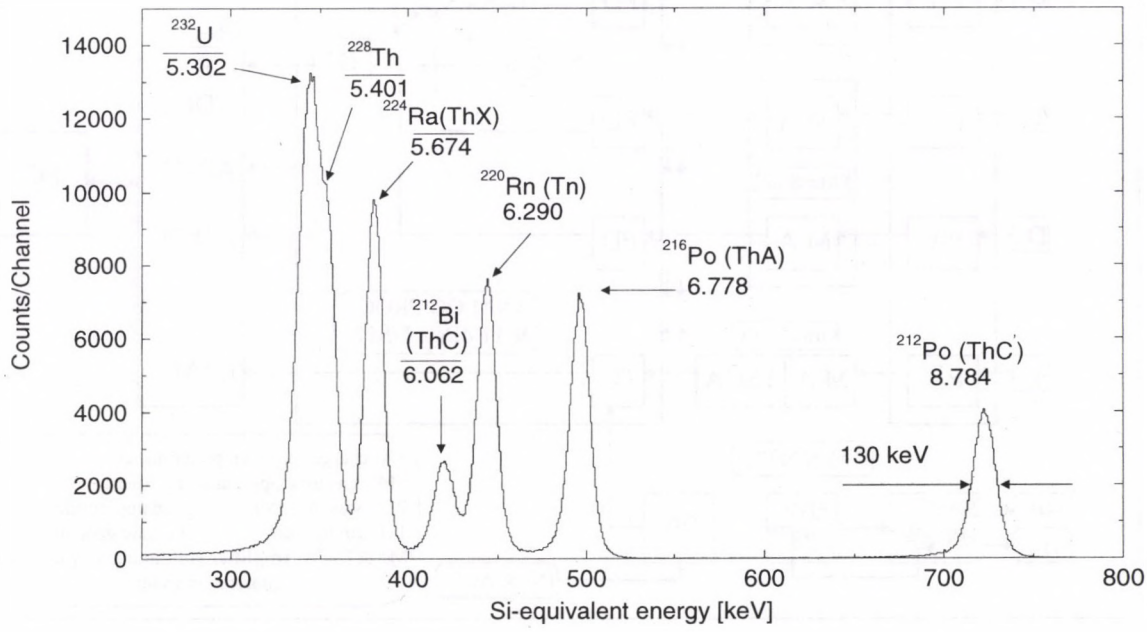

Fig. 1. ^{232}U α-spectrum taken with a scintillations detector

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Data Acquisition System for Beam Profile Monitoring

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The Manne Siegbahn Laboratory (MSL) have developed some non-destructive, beam profile monitors (BPM) for the storage ring CRYRING [1]. The monitoring devices for the transverse density distribution of the stored heavy-ion beams are based on the detection of ionisation products of the beam particles in the residual gas [2, 3]. The horizontal and vertical profiles of the cooled stored ion beams has to be performed with a spatial resolution of +/– (0.2– 0.3) mm. The beam profile monitors are used to

- determine the transverse beam temperature,
- study transverse cooling and heating mechanisms,
- observe the ion behaviour during experiments [4].

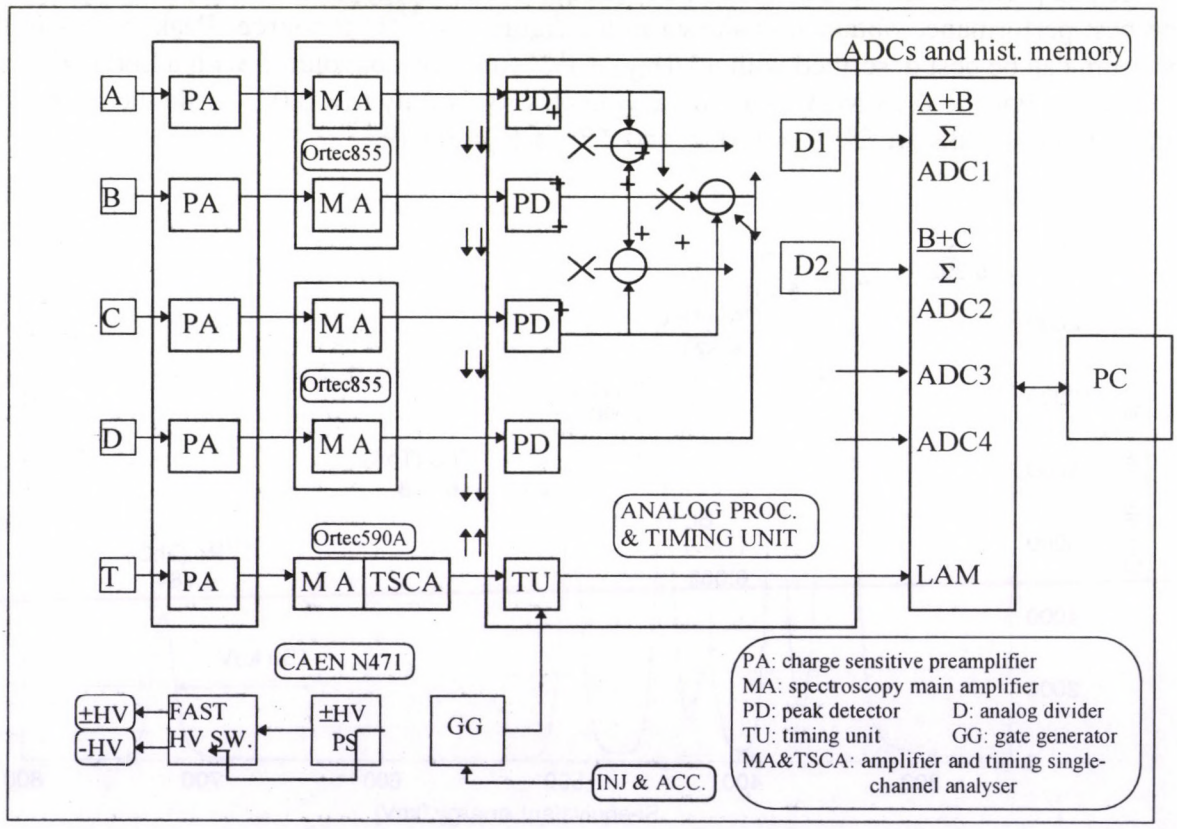

Fig. 1. Block diagram of the readout electronics for BPM

In collaboration with MSL we are developing a high voltage system and PC based electronics for the readout of the detectors.

Detector

Since the ion rates at the CRYRING are relatively low, a chevron assembly consisting of two microchannel plates (MCP) in series and a resistive anode are used to detect the residual gas ions. The MCP is operated in a single-ion counting mode.

High voltage system

The role of the high voltage system is to generate a homogeneous electric field over the active volume using a voltage divider mounted across the vacuum feedthroughs in the preamplifier box, bias the MCP and its resistive anode, switch off the electric field during injection and acceleration using an external gate signal.

Read-out electronics

Position signals from the resistive anode are delivered by the charge-division method. Four charge-sensitive preamplifiers integrate the charges at each corner of the resistive anode. After pulse shaping, stretching and adding two analog dividers computes the event location (fig. 1).

PC Software

A C program reads regularly the collected counts from the incremental memory of the interface card and displays them both in the matrix and projection modes. The data and the pictures on the screen can be saved and restored.

ADCs and histogram memory are described in [5].

[1] K. Abrahamsson *et al.*, *Nucl. Instr. and Meth.* B**79** (1993) 269
[2] T. Quinteros *et al.*, *Nucl. Instr. and Meth.* A**333** (1993) 288
[3] T. Quinteros *et al.*, *Nucl. Instr. and Meth.* A**378** (1996) 35
[4] B. Hochadel *et al.*, *Nucl. Instr. and Meth.* A**343** (1994) 401
[5] J. Molnár *et al.*, ATOMKI Annual Report (1995) 103

Position sensitive avalanche detectors for fission fragment angular distribution measurements

M. Hunyadi and A. Krasznahorkay

In the study of transmission resonances of the $^{235}U(d, pf)^{236}U$ reaction the fission fragment detector designed for angular distribution measurements must have smooth spatial and high total detection efficiency [1].

For this purpose two position sensitive avalanche detectors (PSAD) were constructed [2]. Both consist of two anode wire-planes including 41 and 46 gold plated tungsten wires corresponding to the horizontal and vertical directions, respectively. The wires were placed with a spacing of 2 mm. The cathode of each wire-plane is a thin aluminized mylar foil stretched on a frame. The blown-up demonstration and the cross-section view of the detector can be seen in Fig. 1a and 1b.

Several constructive properties of these detectors were changed, compared to our previous one [2], in order to obey the above expectations:

- The wire-planes face each other, so the cathode foils enable electric screening.
- The diameter of wires was 10 μm instead of 20 μm to reach much higher avalanche amplification smoothing the spatial detection efficiency (Fig. 1c).
- The thickness of the cathode foil is 125 μg/cm^2 instead of 250 μg/cm^2 saving 5–10 MeV kinetic energy for the incoming fragments.

The detectors operated with a cathode-voltage of –500 V. The pressure of the continuously flowing isobuthane significantly influenced the timing properties of the detector. Thus the lowest controllable pressure was 4 mbars corresponding to a time-resolution of < 1 ns.

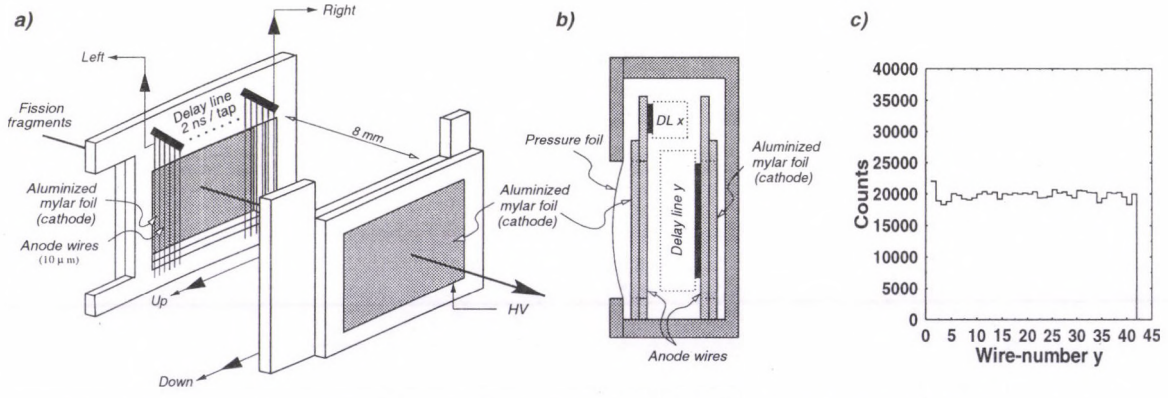

Fig. 1. a) Blown-up view and **b)** cross-section view of the PSAD; **c)** Spatial detection rate

The improved PSAD detectors made their successful usage possible in the measurements of fission resonances performed in Munich at LMU [1].

This work has been supported by the OTKA Foundation, No.7486, and by the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO).

[1] A. Krasznahorkay *et al.*, ATOMKI Ann. Rep. (this year)
[2] M. Hunyadi and A. Krasznahorkay, ATOMKI Ann. Rep. (1995) 93

Large Solid Angle Fission Fragment Detector Array

M. Hunyadi and A. Krasznahorkay

In the study of hyperdeformation large fission fragment detection efficiency is required to obtain sufficient statistics in the $^{235}U(d, pf)^{236}U$ coincidence measurements [1]. Multi-wired avalanche detectors (MWAD) operating with low pressure gas flushing can be reliable means for this purpose due to their high sensitivity and selectivity for fission fragments [2].

Four trapeze-shaped MWADs were set up into an array covering 31% of 4π (see Fig. 1a). Each detector consists of 36 gold plated tungsten wires, as anodes, with a diameter of 20 μm and a spacing of 1.72 mm. The cathode is a massive copper-plate placed at a distance of 3 mm from the wires. Each detector has a sensitive surface of 56 cm^2. The cross-section view of the detector can be seen in Fig. 1b.

During the operation 4 mbar isobuthane gas was flushing through the detectors. The cathode-voltage was –500 V, and all the wires connected to each other on ground potential were read out via fast preamplifiers, which gave ≈ 400 mV signals. The discriminator levels were adjusted to cut off the low energy signals, which were due to the light charged particles. This selective sensitivity for different particles could be checked analyzing the energy spectrum of the signals. Figure 1c clearly shows the possibility of distinction between the events caused by the fission fragments and the light particles.

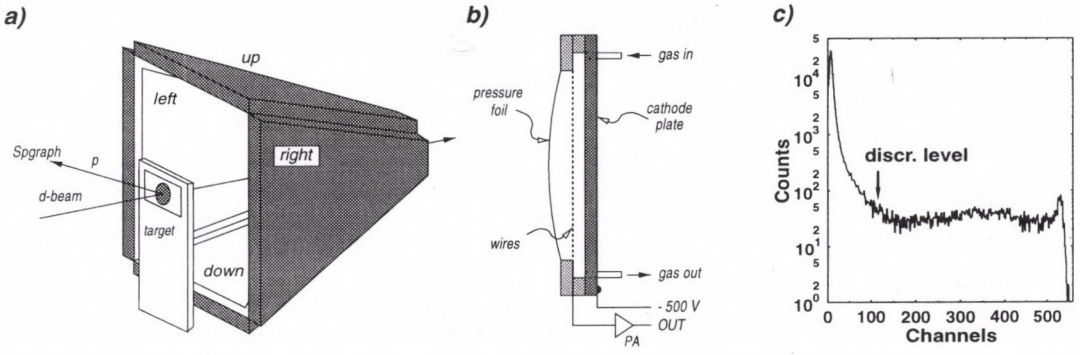

Fig. 1. a) The schematic construction of the MWAD-array; **b)** cross-section view of the MWAD; **c)** energy-spectrum of signals

Using adequate discrimination levels during the $^{235}U(d, pf)^{236}U$ experiment the detectors operated with 3.5, 3.3, 4.0 and 3.5 kHz counting rate corresponding to the Up, Down, Left and Right positions in the array. The final effective counting rate was 13 kHz showing the electronic cross-talk between the detectors less than 10% of all firing events.

[1] A. Krasznahorkay *et al.*, ATOMKI Ann. Rep. (this year)
[2] M. Hunyadi and A. Krasznahorkay, ATOMKI Ann. Rep. (1995) 93

Energy Response of a Novel Compact Ge+BGO Spectrometer for 10–20 MeV γ-rays

M. Csatlós, A. Krasznahorkay, J. Bacerar,[1] A. Balanda,[2] I. Diószegi,[3] W. Przygoda[2] and S. Schadmand[1]

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[3] Institute of Isotopes of the Hungarian Academy of Sciences, Budapest, Hungary

During a long-term research project of the Eindhoven University of Technology with Canberra, Olen in Belgium a novel γ-ray spectrometer was developed. The new spectrometer employs the old idea of Compton suppression by surrounding the Ge detector with a BGO crystal, but in the new design the two crystals are encapsulated in a compact way having no absorbing materials in between [1]. The energy response of such a spectrometer was studied in adding mode, the energy of the γ-quanta was reconstructed by summing (off-line) the energies deposited in coincidence in the Ge detector and in its BGO suppression shield.

The performance of the spectrometer at higher energy was tested in an experiment in Orsay in the $^{12}C(p, p'\gamma)$ reaction. For the precise simulation of the interaction of γ-rays with the detector materials GEANT (geometry and tracking) [3] code was employed. Simulated full range response functions of the combined Ge+BGO system are shown together with the experimental spectra in Fig. 1 for 4.44 and 15.1 MeV, respectively. The photopeak energy resolution is 1.65%, while the efficiency is $\varepsilon \approx 17.02\%$ for $E_\gamma = 15.1$ MeV.

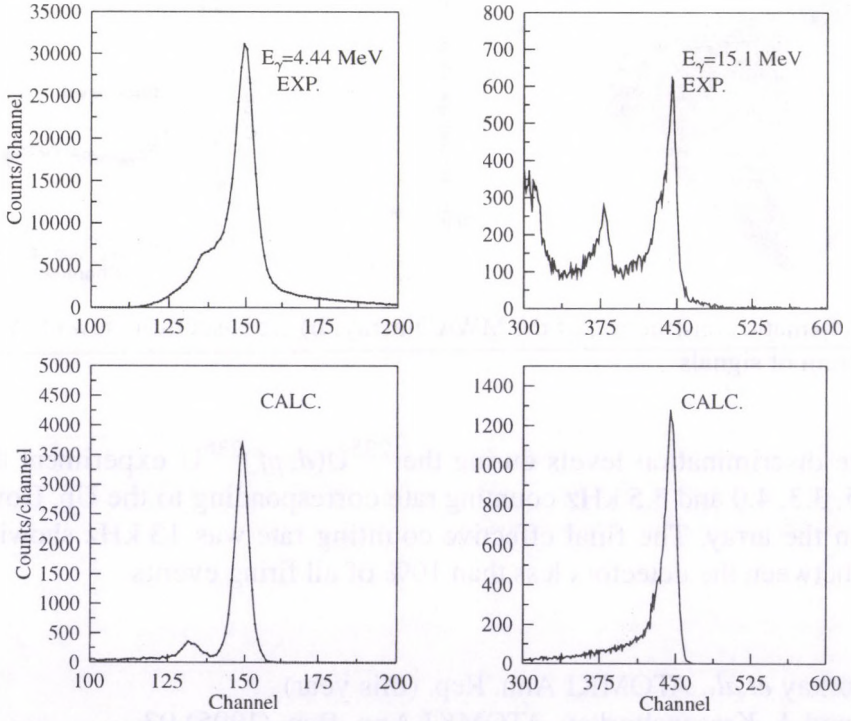


Fig. 1. Experimental and calculated response function for 4.44 and 15.1 MeV γ rays

This work has been partly supported by the OTKA Foundations No. 7486, and by the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO).

[1] M.J.A de Voight *et al.*, *Nucl. Instr. and Meth.* **A356** (1995) 362
[2] R. Brun *et al.*, GEANT3 CERN/DD/ee/84-1 (1987) document

A new proportional drift chamber readout system

J. Molnár, A. Krasznahorkay, J. Gulyás, Gy. Hegyesi and D. Sohler

A new proportional drift chamber readout system has been designed and implemented to provide complete instrumentation for Multi-Wire Proportional Chamber (MWPC) of the ATOMKI split-pole magnetic spectrograph. The system is based on the experience gained with the previous one constructed on delay-line readout concept [1]. The block diagram of the new readout system is shown in Fig. 1.

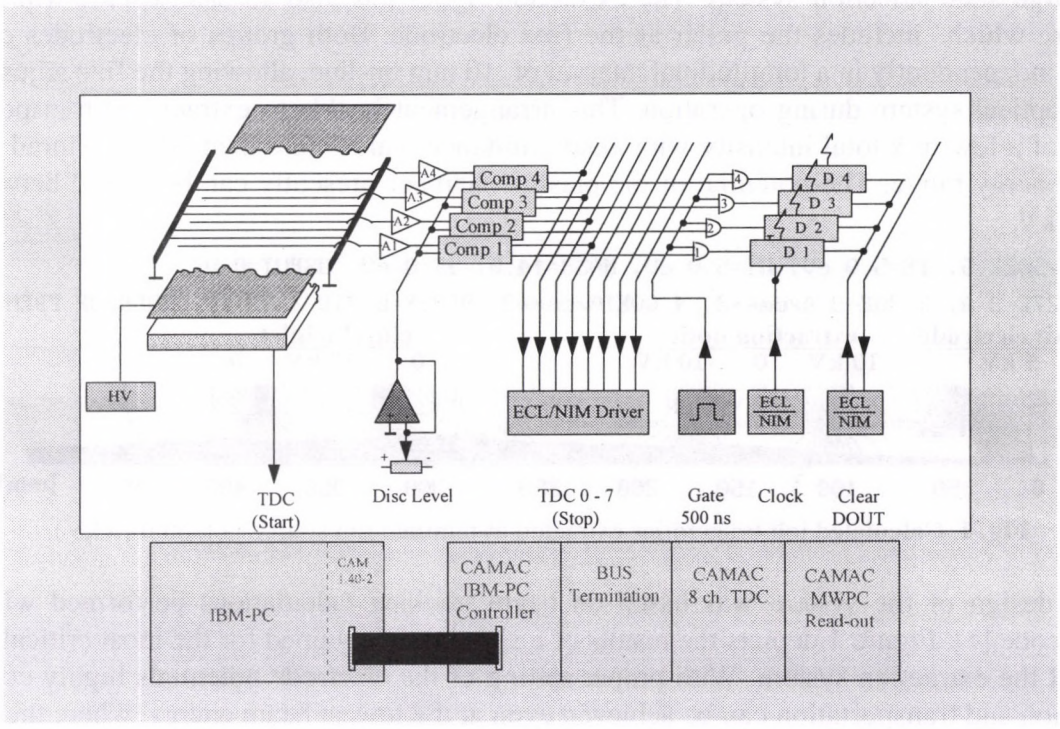


Fig. 1. Block diagram of the drift chamber readout system

The horizontal position and angle of the incoming particle are calculated from the measured drift times, for which the start signal is generated by a plastic scintillator. The set-up contains a circuitry to amplify, discriminate, latch and encode the MWPC signals, implemented on a single chamber-mounted card. High performance and simplicity are achieved through the use of custom integrated circuits, a quad-preamlifier (MQS104A LeCroy) and an ultrafast dual-discriminator (AD96687 Analog Devices). The quad-preamplifier is a high gain transimpedance amplifier, combined with a shaping amplifier. The output pulse is optimized for fast proportional chambers. This integrated circuit is manufactured as a 4-channel device with protection elements added to the input circuitry. The read-out and the control of the set-up are provided by additional CAMAC controller and driver modules.

The custom backplane provides the bus and daisy chain wiring to connect up to 5 by 16 input cards forming together one readout stream. This backplane also distributes the power, as well as the GATE, CLOCK, CLEAR and DOUT signals to the cards.

The production, assembly and functional test measurements of the surface-mounted boards before final implementation are in progress.

This work has been partly supported by the OTKA foundation No. 7486, and by the Nederlandse Organisatie voor Watenschappelijk Onderzoek (NWO).

[1] A. Krasznahorkay *et al.*, ATOMKI Annual Report (1995) 94

The Extraction System of the ECR Ion Source

Z. Kormány, S. Biri

The multiply charged ions, generated in the ECR-plasma, are extracted from the plasma chamber and transported to the charge state analyzing magnet by an electrostatic multi-electrode lens system. This system has two main groups of electrodes—the extraction lens group pulls the ions from the plasma and forms a nearly parallel beam. It is then transported through an einzel triplet, which produces a beam waist of about 10 mm diameter at the entrance point of the charge state selection system. The extraction optics has also an electrostatic triplet-like structure which includes the puller as the first electrode. Both groups of electrodes can be moved independently in a longitudinal interval of 10 mm on-line, allowing the fine adjustment of the optical system during operation. This arrangement is able to extract and transport ion beams of a few mA total intensity with axial emittance values less than 50 mm×mrad in the whole energy range. The potential of the plasma chamber presently can be varied between 5 and 30 kV.

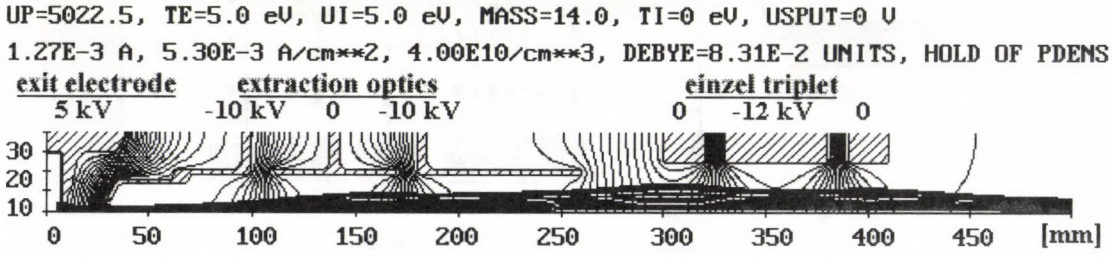


Fig. 1. Calculated ion trajectories extracted at minimal ion source potential (5 kV).

The design of the system was based on beam tracking calculations performed with the IGUN code [1]. Figure 1 depicts the results of a simulation obtained for the most critical operation of the extraction system. With proper setting of the electrode potentials highly efficient extraction and transportation can be achieved even at the lowest beam energy, where the space charge effect is very strong.

The first tests of the system were carried out with Ar beams at 10 kV source potential. Table 1 shows the measured total ion beam intensity and current values lost on the elements of the extraction system. The calculated transported beam intensities and transport efficiencies are given, too. In these experiments the ECR ion source was optimized for Ar^{8+} ions.

Table 1. Measured beam intensities (in mA) and calculated transport efficiencies

I_{total}	I_{puller}	I_{einzel}	$I_{transp.}$	Efficiency
1.1	0.4	0.1	0.6	54.5 %
0.7	0.3	0	0.4	57.1 %
0.7	0.2	0	0.5	71.4 %

In the near future we continue testing the system with other settings of the source in order to make more comparisons with the simulations and to improve further the extraction and transport efficiencies.

[1] R. Becker, W.B. Herrmannsfeldt, *Rev. Sci. Instr.* **63** (4), April 1992, 2756–2758.

The first multiply charged heavy ion beams from the ECR ion source

S. Biri, J. Vámosi, A. Valek, Z. Kormány and J. Pálinkás

During 1996 the basic construction of the ECR ion source* has been finished. After several plasma and X-ray measurements [1, 2] the first beam extraction experiments have been carried out in November–December. Presently the ion source has a very simple beam line: the electrostatic extraction lens system focuses the beam to the entrance focus point of a 90 degrees analysing magnet and in the other focus point (object point) a simple Faraday cup measures the selected beam component intensity.

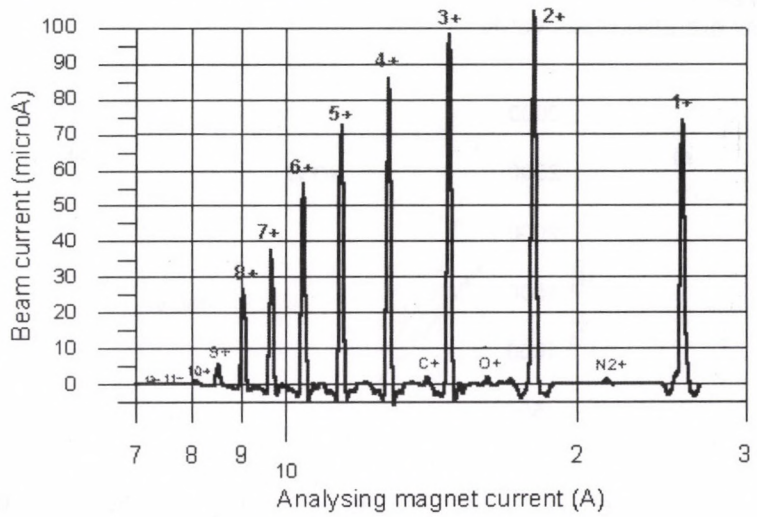


Fig. 1. Typical ECRIS spectrum where the beam components (having different charge-to-mass ratios) are drown vs. the bending magnet current. Working gas: argon, source potential: 10 KV, microwave power: 500 W. The ion source was optimized for Ar^{8+}. The table below the figure summarizes the obtained highest argon beam intensities.

Ar charge state	1+	2+	3+	4+	6+	7+	8+	9+	11+	12+
Beam (μA)	475	228	98	86	56	39	35	10	0.17	0.004

So far only residual gas and argon spectrums have been taken while we were partly restricted with some tuning parameters (magnetic field strength, puller position, microwave power etc.). In 1997 we continue the development of the ECR ion source in order to find its optimal working parameters and to reach higher charge states and intensities for the most usual ions (H, He, C, N, O, Ne, Ar, Kr, Xe). On the other hand the usage of the highly charged heavy ion beams for low energy atomic physics experiments will also start.

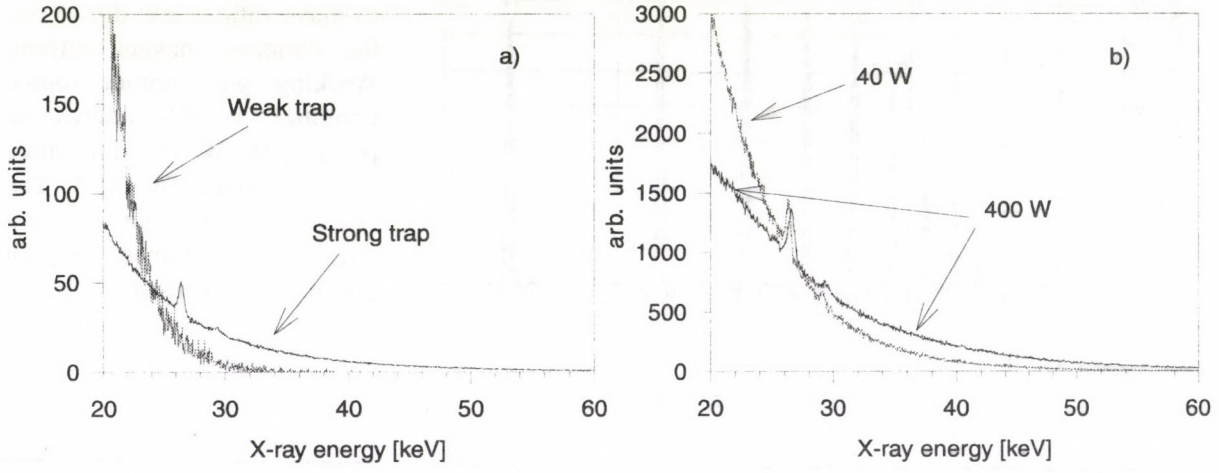
* The ECRIS program was supported by the 'Human Resources' project (OTKA No. A077/1992), by the OTKA (F013961 and F15088) and by the FEFA (HU-3313 697/2-AA-1and HU-1995).

[1] S. Biri, J. Vámosi, A. Valek, Z. Kormány, E. Takács, J. Pálinkás, *Nucl. Instr. Methods* B (1997) (under printing; presented in FIAC'96, September 1996, Debrecen, Hungary)
[2] See J. Vámosi *et al.*, this Annual Report

Plasma diagnostics on the ECR ion source

J. Vámosi, S. Biri and E. Takács

The first plasma by electron cyclotron resonance in a fully closed magnetic trap was generated in the ECR ion source* in August 1996. Before the beam extraction experiments [1], we carried out some X-ray measurements [2] (using a Si(Li) detector) in order to obtain direct information about the plasma. The detector had a lower detection threshold of about 2 keV and was placed on the optical axes of the plasma chamber. The window of the vacuum chamber was made of plexi-glass (7 mm). The goal was to gain information on the electron energy distribution function. The energetic electrons bump against the wall of plasma chamber producing bremsstrahlung. in the range of range of 1–100 keV. The characteristic peaks of the material of the chamber and of the working gas are also observable.



We examined the effects of the tunable ECR parameters on the energy distribution. The first parameter was the axial magnetic field. Figure a) shows the spectrum of the bremsstrahlung at minimal (week trap) and maximal (strong trap) coils currents. Figure b) shows the X-ray spectrum at two different high frequency powers: at low (40 W) and high (400 W) power. It can be seen that the stronger magnetic electron-trap produces more high energy X-ray photons, that is more high energy electrons. The similar effect can be observed in the case of higher RF power by the appearance of the high energy tail.

* The ECRIS program was supported by the 'Human Resources' project (OTKA No. A077/1992), by the OTKA (F013961 and F15088) and by the FEFA (HU-3313 697/2-AA-1and HU-1995).

[1] See S. Biri *et al.*, this Annual report.
[2] S. Biri, J. Vámosi, A. Valek, Z. Kormány, E. Takács, J. Pálinkás, *Nucl. Instr. Methods* B (1997) (under printing; presented in FIAC'96, September 1996, Debrecen, Hungary)

Post-irradiation sensitization of CR-39 track detector in carbon dioxide atmosphere

I. Csige

The effect of sensitization of CR-39 type etched track detector by post-irradiation treatment in carbon dioxide atmosphere was first reported by Fujii *et al.* [1].

In the present experiment we have used sheets of TASTRAK (Bristol, England), CR-39 type track detectors. Detectors were irradiated by a thin ^{252}Cf fission fragment and alpha particle source in near contact geometry at normal air conditions. Exposure time was about half minute. Treatment in carbon dioxide atmosphere of CR-39 was made in a common soda siphon at room temperature. Partial pressure of air in it was 1 bar, while partial pressure of carbon dioxide was 6 bars. The exposure time to carbon dioxide was 1 week. After treatment and before etching the detectors were kept in normal air for 2 min. Etching was done in 6.25 N NaOH solution at (70 ± 0.2) °C for 5 hours.

Figure 1 shows the effect of carbon dioxide on the sensitivity of CR-39 to 6 MeV alpha particles as a function of storage time in CO_2. The sensitivity (S-1) of treated CR-39 increased as a function of treatment time and it was more than two times higher after a week in carbon dioxide than that of untreated sample.

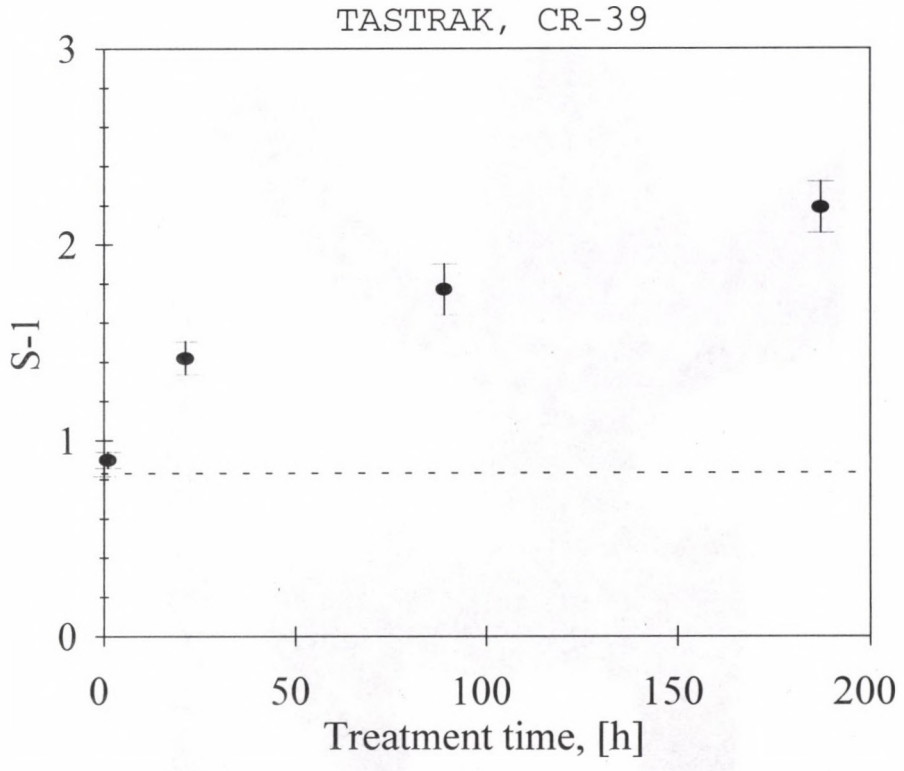


Fig. 1. Sensitivity of CR-39 to 6 MeV alpha particles as a function of post-irradiation treatment time in 6 bar carbon dioxide. Dashed line corresponds to untreated detector sensitivity.

[1] Fujii M., Yokota R., Kobayashi T. and Hasegawa H. (1995) Sensitization of polymeric track detectors with carbon dioxide. *Radiat. Meas.*, **25**, Nos 1–4, 141.

Activities at the scanning proton microprobe

I. Rajta, A. Simon, I. Uzonyi, M.Á. Ontalba,[1] I. Borbély-Kiss, L. Bartha, A. Nagy, E. Koltay and Á.Z. Kiss

[1] University of Sevilla, Sevilla, Spain

The following subjects have been performed in 1996 on the scanning proton microprobe.

Technical developments

Because of He^+ and proton beams at energies as high as 3.8 MeV need high currents on the focusing quadrupole magnets, an efficient cooling was introduced using a suitable ventilation. In addition an electron source was installed in the chamber to neutralize the positive charging of insulating samples.

Applications

In *art and archaeology* several artefacts of ring stones (Fig. 1) and Roman glasses as well as samples of paint layers [1] and Spanish potteries were analysed. In the latter ones the interest was concentrated on the small granules (mostly quartz inclusions) in the clay material.

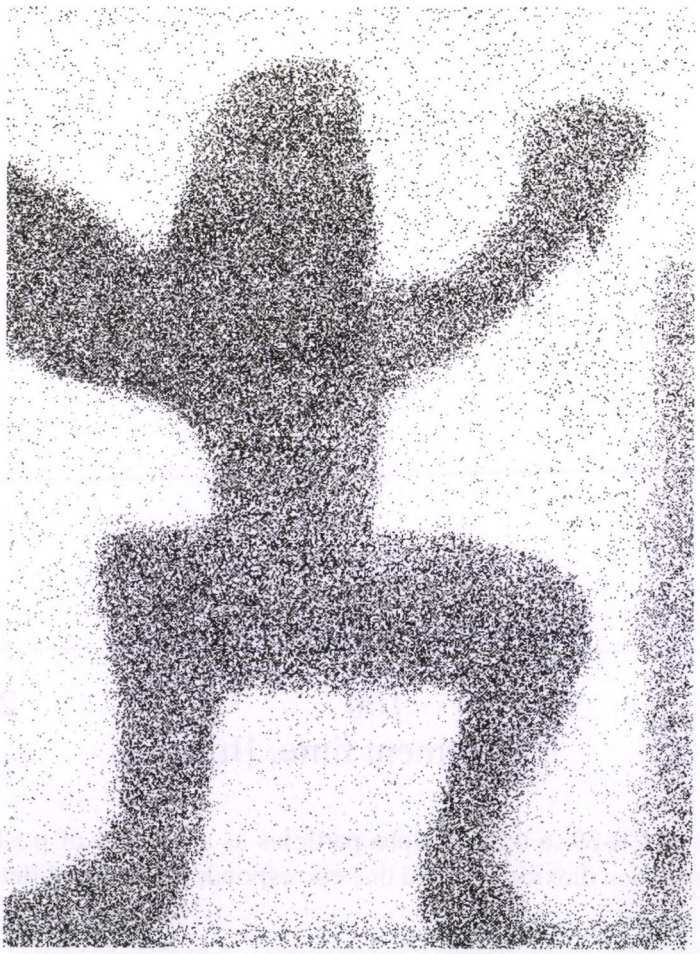


Fig. 1. Elemental mapping of the ring stone "sacrificing Amor" (Hungarian National Museum, Budapest). The Si distribution is seen in the small gravings.

Aerosols (collected in Debrecen, and Chile Lonquimay Volcano during an eruption) were analysed for individual aerosol particles [2]. It is possible with our optical microscope coupled CCD camera to find any desired aerosol particle as small as about 10 μm.

In the framework carried out together with the Geological Institute of Hungary 30 pieces of *spherules* were analysed for major and trace elements. Some of the samples found to be quite inhomogeneous which was not possible to see by bulk analyses, such as NAA, while EPMA was not sensitive enough for the trace elements.

RBS technique combined with the scanning microprobe proved to be a useful method for the determination of the Sm concentration through the *surface of targets* produced electrophoretycally for nuclear reaction measurements of astrophysical interest.

Thin and narrow $TiOSnO_x$ *layers* were measured also with RBS in co-operation with Attila József University, Szeged.

Education

Laboratory exercises were organized for undergraduate students and part of the research activities were devoted to PhD works.

[1] I. Rajta, M.Á. Ontalba, E. Koltay, Á.Z. Kiss, *Study of white lead paint layers by the Debrecen nuclear microscope*, NIM B, accepted.

[2] E. Koltay, I. Borbély-Kiss, Gy. Szabó, Á.Z. Kiss, I. Rajta, E. Somorjai, E. Mészáros, Á. Molnár, L. Bozó, *Characterization of regional atmospheric aerosols over Hungary and qualification of individual volcanic particulates by PIXE elemental analysis*, Report NAHRES IAEA, accepted.

Status Report on the Cyclotron

A. Valek and Z. Kormány

The planned operation of the cyclotron was similar to that of the previous years. The utilization of the machine was concentrated to 9 months; January, July and August were reserved for maintenance and holiday.

The overall working time of the cyclotron was 3873 hours with break down periods amounted to 62 hours. The cyclotron was available for users during 3383 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 the beam preparation and waiting the start of an irradiation was collected separately and totalled to 545 hours.

The modernization of the control and vacuum systems of the cyclotron is in progress in the frame of the Technical Assistance Program (project code number HUN/4/013) of the International Atomic Energy Agency, Vienna.

Table 2. Effectively used beam time

Projects	Beam time (hours)	%
Particle and γ spectroscopy	615	30
Neutron physics	80	4
Nuclear astrophysics	279	14
FERMI	42	2
Isotope production	1010	50
Total	2026	100

Activities at the Van de Graaff Accelerator Laboratory

L. Bartha, Á.Z. Kiss, E. Koltay, A. Nagy, E. Somorjai and Gy. Szabó

During 1996 the beam time of the VdG-1 machine amounted to 696 hours. The accelerator delivered proton and helium beams for atomic physics during 220 and 421 hours, respectively.

The 5 MeV Van de Graaff machine was operating for 1957 hours during this period. Mainly protons (85%) and $^4He^+$ ions (15%) were accelerated.

The beam time was distributed among different research subjects and education (laboratory practices for undergraduate and PhD students) as it is shown in Table 1. Test runs (3 hours) remained much below 1% of the total beam time.

Table 3. Time distribution among different research activities at VdG-5

Field	Hours	%
Atomic physics	520	27
Nuclear physics	225	11
Analytical studies	363	19
Analytics on the microprobe	732	37
Education	119	6
Total	1957	100

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3. Pál K.F.,
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Magyar Tudományos Akadémia Atommagkutató Intézete
A kiadásért és szerkesztésért felelős
Dr. Lovas Rezső, az Intézet igazgatója
Sokszorosítás:
REXPO Kft. Nyomdaüzeme, Tel: 52-417-266
Felelős vezető: Rácz János
Törzsszám: 65788
E-print: EP Systema BT, Debrecen
Debrecen, 1997. április